COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

December, 1945

Night View of Jennison Station, New York State Electric & Gas Corporation

Features of the Jennison Station ▶

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DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME 17 **NUMBER 6**

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Editorial

Moderate Drop in Energy Output

In the interim following V-J Day and re-establishment of normal peacetime conditions, an appreciable drop in demand for electric energy was anticipated. It is too early to assess the extent, but some indication is afforded by figures just released by the Federal Power Commission covering output up to October 31. These show that month's output of electricity by utilities to be 2.6 per cent under that of September; and for the twelve-month period ending October 31, 1945, the total was $1^1/_2$ per cent under that for a like period ending October 31, 1944. Moreover, combined utility and industrial output of electric energy was 8.1 and 1.9 per cent less for these respective periods. This indicates a greater falling off in privately generated power than in the central station load. However, the combined decrease is not as great as might have been expected.

Estimated electric energy requirements to be supplied by utilities in 1946, as reported from this source, are 5.2 per cent under the 1945 figure, which, in turn, was 2.9 per cent under the all-time high of 225 billion kilowatts in 1944.

Meanwhile net additions to capacity continue to increase and involve many extensions previously planned but held up during the war because of the materials situation.

The Montaup Unit

If attendance may be taken as a criterion of interest, the very large number that crowded the A.S.M.E. session on the Montaup forced-circulation boiler would indicate a strong desire on the part of power engineers to learn more about this type of unit. For this reason considerable space in this issue is being devoted to abstracts of the group of four papers dealing with three years' operating experience, for the benefit of those readers who were unable to be at the session. Unfortunately, space limitations make it impossible to include many of the interesting details brought out by the authors, although an effort has been made to cover the most essential points.

As in all pioneer installations involving departures from usual practice, certain new problems were encountered. The principal one concerned feedwater treatment which now appears to have been solved satisfactorily. No troubles with the boiler itself were attributable to the high pressure, although this did involve some alterations in the pumps. It is significant that no major design changes were necessary in the boiler. The operating procedure had to be adjusted to the conditions and the desirability of full instrumentation became apparent.

Advantage was taken of the opportunity to take careful and complete measurements of all factors during operation and many valuable data were obtained. This was rendered possible by close cooperation between the consulting engineers, the operating company and the equipment manufacturers, and the results afford a valuable contribution to literature on forced circulation.

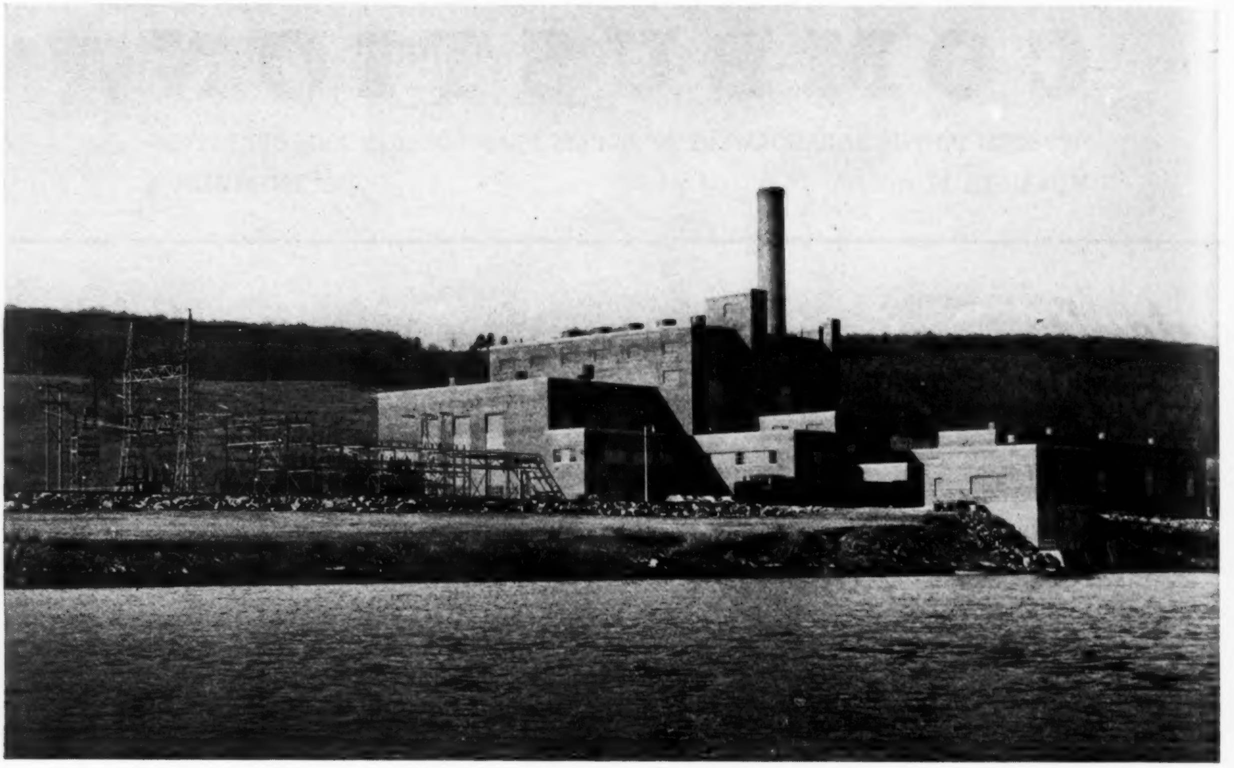


Fig. 1—View of station from opposite river bank

Features of the JENNISON STATION, New York State Elec. & Gas Corp.

This new station, located near Bainbridge, N. Y., contains a 30,000-kw turbine-generator receiving steam at 650 psi, 825 F from two 200,000-lb per hr two-drum bent-tube boilers which burn No. 4 buckwheat anthracite on forced-draft traveling-grate stokers. These stokers, each of 672 sq ft grate area, are the largest of this type yet employed in central station service.

By H. C. SCHWEIKART

Gilbert Associates, Inc., Reading, Pa.

IN THE early part of 1942, a power supply study was prepared for the central region of the New York State Electric & Gas Corporation. This service area, located in the central part of southern New York State, had established a maximum hourly demand of 177,035 kw in December of the previous year with an average growth of 7400 kw per year for the years between 1932 and 1939. A report of the Federal Power Commission in 1941 estimated the future growth of this area to be 10,000 kw per year. The principal steam generating stations then serving the area were located at Binghamton, Dresden and Elmira. Some additional capacity was also available at several small hydro and other steam generating stations.

The power supply study concurred with the Federal Power Commission's report regarding the estimated rate of growth. It further indicated that the system in this area had reached its limit of dependable installed generating capacity. Therefore, a recommendation was made to erect a new steam generating station in the Oneonta District. This district, located at the eastern end of the service area, was without appreciable generating capacity and at the end of a long, single transmission line. Installation of a unit here would result in improving the distribution and aid in stabilizing the facilities throughout the system.

A decision was made to proceed on the project at once. Gilbert Associates, Inc., Reading, Pa., were engaged as consulting engineers to design and supervise the construction of the project, and an application was submitted to the War Production Board which granted approval in March 1942.

Studies were then started to determine the capacity, steam conditions and other factors involving the design of the station. In the meantime, a number of sites were investigated as to availability, soil conditions, railroad facilities, flood conditions, condensing water, etc.

In October of the same year permission for continuing the project was revoked by the War Production Board; but the New York State Electric & Gas Corporation, sensing a critical need for the additional generating capacity, decided to proceed with the preliminary engineering on a limited scale even though purchase orders for equipment could not then be put through.

Studies were made for electric generating units of 25,000 and 35,000 kw capacity at both 650 psi, 825 F and 850 psi, 900 F steam conditions with both single- and two-boiler installation. Considerable study was given to the fuel-burning equipment, bituminous coal in pulverized form as well as stokers being considerd. Also, anthracite was investigated for burning on a stoker and in pulverized form with both unit and storage systems.

A plant site approximately one mile south of the Village of Bainbridge and 32 miles northeast of Binghamton was ultimately selected for the project. This site, lying between the Susquehanna River and the double-tracked main line of the Delaware and Hudson Railroad, most nearly suited the conditions considered important for this project. New York State highway Route No. 7, running between Binghamton and Albany, parallels the railroad at this point. Ample condensing water for two units (ultimate capacity of the station) together with transmission line right-of-way, highway and railroad facilities enhanced its value as a location for a steam-electric generating station.

As industrial plants increased their production of war materials, a critical shortage of generating capacity became evident. Becoming cognizant of the seriousness of the situation, the War Production Board decided to authorize the installation of an electric generating unit somewhere in the vicinity of eastern New York State. Investigation disclosed that the installation of a unit at Bainbridge by the New York State Electric & Gas Corporation would most nearly satisfy all requirements.

Representatives of the New York State Electric & Gas Corporation together with their consulting engineers were then called to confer with the War Production Board. The latter agreed to receive an application for formal authorization of the Jennison Station based on the installation of one 30,000-kw, single-cylinder, single-flow turbine to operate at 650 psi, 825 F total temperature, and connected to a hydrogen-cooled generator; two 200,000-lb per hr stoker-fired steam generators to burn No. 4 buckwheat anthracite; the elimination of dual-driven and spare equipment, and the use of steel for such items as coal bunkers, etc. A formal application was submitted to the WPB October 13, 1943, and approval to proceed with the project was granted November 23, 1943.

Throughout most of the design and construction period the project was referred to as the Bainbridge Station. It has now been officially named Jennison Station in honor of Ralph D. Jennison, President of the New York State Electric & Gas Corporation.

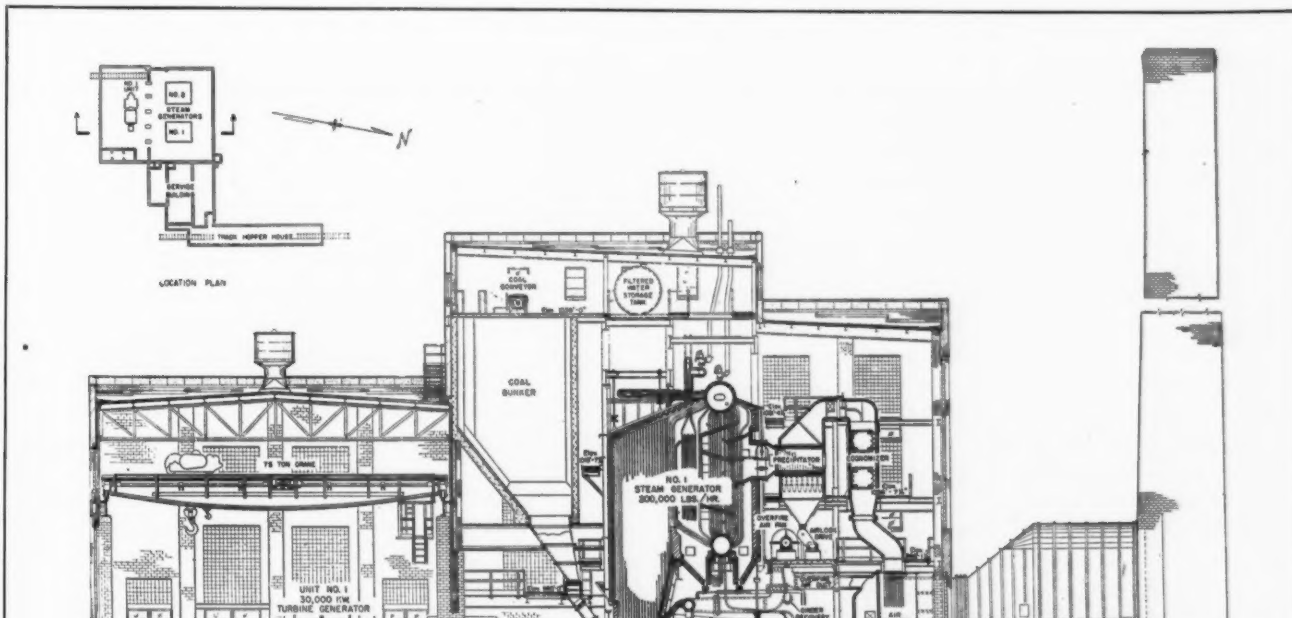


Fig. 2—Sectional elevation of station

Start of Construction

The George A. Fuller Company of New York was awarded the general contract for the project. Hauling fill for the railroad siding started January 18, 1944, and after the erection of the temporary construction buildings, actual excavation for the main building began May 19.

The entire excavation was kept dry throughout the construction of the building foundation by means of a Moretrench wellpoint system. The predrainage of the excavation area eliminated the use of sheet piling or shoring even though some parts of the excavation were 26 ft below the normal river level and less than 100 ft away. A concrete plant was set up at the plant site to furnish all the concrete requirements.

Lack of field labor, particularly steel workers, brick masons and electricians slowed down the construction work. Laying brick in the main building walls was in progress throughout the winter with temperatures as low as 28 deg F below zero. Temporary partitions of Celetox wall board and an Insulite sheathing enclosure around the bricklayer's scaffolds permitted the brick masons to continue their work. Four hot-air furnaces located inside the main building and salamanders placed less than 10 ft apart on the brick masons' scaffolds around the building supplied the necessary building heating so that construction could proceed. Prior to the erection of the temporary enclosure, the brick masons had been able to work only part of one day during an entire week.

Building Features

The plan of the power station and dependency units form an interconnected group of structures comprising the main building, housing the steam and electric generating equipment together with their auxiliaries; and dependency areas consisting of a two-story structure, the first floor devoted to a machine shop, storeroom, general offices, first-aid room, men's wash and locker rooms, and the second floor to a chemical laboratory, meeting room, station control room, battery room, water-treatment room, and a women's combination toilet and rest room. A track hopper house for unloading coal and thawing frozen coal cars during winter months, completes the group.

A combined screen house and chlorination treatment building is located at the river bank. This, while not a part of the above group, is connected to the turbine room basement by a pedestrian traffic tunnel to afford ease of access between buildings. Separated from the rest of the structures is a two-car garage with additional space for the storage and inspection of the bulldozer used in connection with storage and reclaiming coal.

The design of all buildings, with the exception of the garage, incorporates concrete foundations, structural-steel framing, red brick walls with glass-block panels and limestone trim and coping, precast cement roof slabs, roof insulation and built-up roofing. The garage design embraces concrete foundations and inspection pit, brick walls and a poured-in-place concrete roof consisting of beams and slab.

The interior finish of the turbine room walls from the operating floor to the roof is cream colored glazed tile, trimmed with indian red tile. This same wall finish is used throughout the offices, meeting room, washrooms, chemical laboratory and control room. The walls of the boiler room are finished in tile for a height of approximately 15 ft and the balance is red brick. The floor finish of both turbine room and boiler room basement and operating floors, battery room and water treatment room is red quarry tile.

All walkways and operating platforms, excepting those of concrete or quarry tile, are grating; and for stairways, grating treads with abrasive nosings are used throughout. The only exception is the main entrance stairway, which has terrazzo treads and landings.

Building heating and steam required for coal-car thawing is supplied by two 125-hp, 150-psi oil-fired Erie City "Economic" boilers. Steam is supplied at 10 lb to copper convectors for heating the offices, to "Climate Changers" in the control room and meeting room, to a ventilating unit in the locker room and to Wing utility-type unit heaters in the turbine room and boiler room, track-hopper house and garage. The "Climate Changer" also provides a constant introduction of fresh air and can serve as a cooler during the summer months.

Ventilation of both turbine room and boiler room is accomplished by the admission of air at ground level and exhausting through power-driven roof ventilators. The forced-draft fans located in the basement draw air from within the building during warm weather and from outside the building during cold weather. Various combinations of these two extremes can be obtained as desired.

The turbine and boiler room operating floors are at the same elevation without a common wall between them. Most boiler and turbine room auxiliaries such as boiler feed pumps, fans, ash handling, hydrogen control, etc., are located in the basement.

Steam-Generating Unit

The initial steam generator installation consists of two Combustion Engineering Company, two-drum units designed for 750 psi pressure. Each has a rated capacity of 200,000 lb per hr with steam leaving the superheater outlet at 675 psi 835 F total temperature. These units are the largest stoker-fired steam generators burning anthracite coal ever installed in a central station. Two bypass dampers located at the boiler outlet are so arranged that positive control of the quantity of gases passing the superheater surface is obtained and the superheater outlet temperature of 835 F is maintained for all steam flows above 115,000 lb per hr.

The front, rear and roof furnace water walls are made up of plain tubes with finned tubes on the side walls.

A short front Detrick sectionally supported tile ignition arch is provided, and the long rear arch over the stoker is formed by the rear furnace tubes backed up by special tile.

The "Elesco" superheater, of 4480 sq ft, is of the interbank convection type and of all-welded construction. The "Elesco" economizer, of 7670 sq ft, is of the continuous loop, finned-tube construction, and of counter flow, single-pass design. A tubular-type air heater of counter-flow design with two air passes forms a part of each unit.

The arrangement of these component parts of the steam-generating unit is shown in the sectional elevation of the plant, Fig. 2.

Fig. 3—Firing aisle showing the two 672-sq ft traveling grate stokers

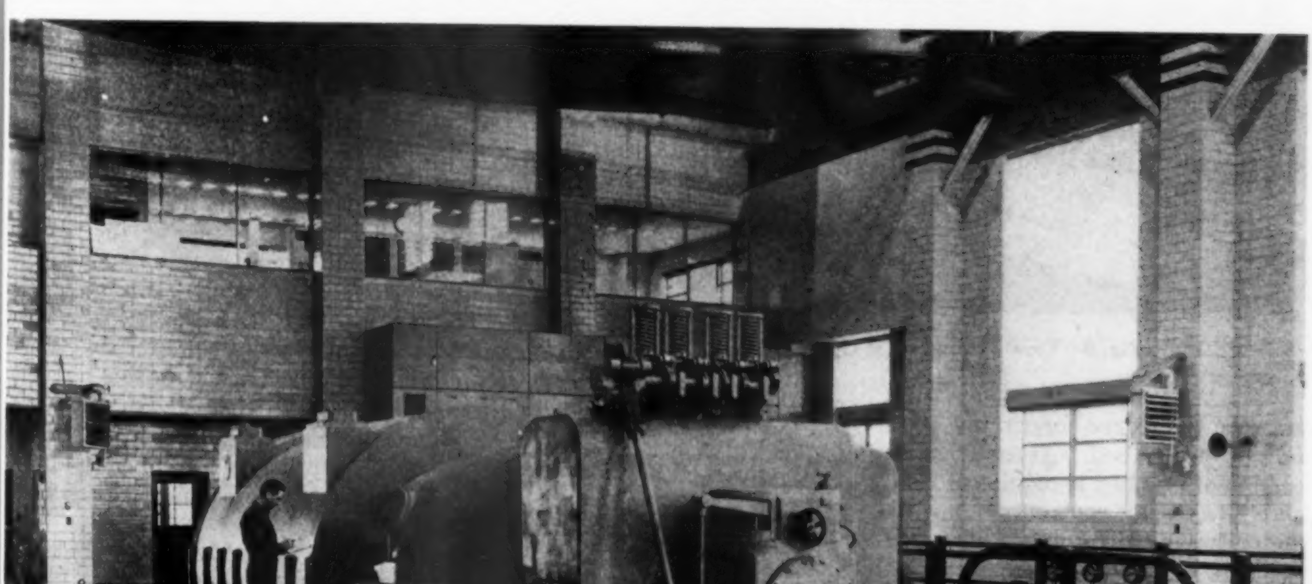


Fig. 4—Initial installation includes one 30,000-kw turbine-generator

A complete set of Vulcan revolving soot-blower elements is supplemented by a retractable element installed near the top on each side of the furnace to keep the entrance to the first pass clear. These retractable units are air-operated and remote-controlled from the boiler board. No soot-blower elements are provided for either the economizer or air heater.

Largest Traveling Grate Stokers in Utility Service

The C-E Lloyd type traveling grate stokers are 24 ft wide by 28 ft long, representing a grate surface of 672 sq ft, and designed to burn small size anthracite, (No. 4 buckwheat). Forced-draft combustion air, preheated to 290 F temperature is supplied under the entire grate surface. The under side of the fuel bed is divided from front to rear into nine separate compartments, each of which is provided with a damper to control the combustion air. The three compartments at the rear of the stoker are further divided into three zones, each controlled by an individual damper. An adjustable vertical gate, extending the full width of the stoker and located between the stoker hopper and grate, governs the thickness of the fuel bed. At full boiler rating, approximately $4^1/_2$ in. of fuel bed is required. The stoker is driven by an electronically controlled Louis Allis adjustable-speed motor having a 6-to-1 speed range. Maximum grate speed is 90 ft per hr and the minimum 14.8 ft per hr. To obtain the desired turbulence of the products of combustion, preheated overfire air is supplied to the furnace through the nose of the rear arch. This is handled by a separate fan taking air from the air heater outlet.

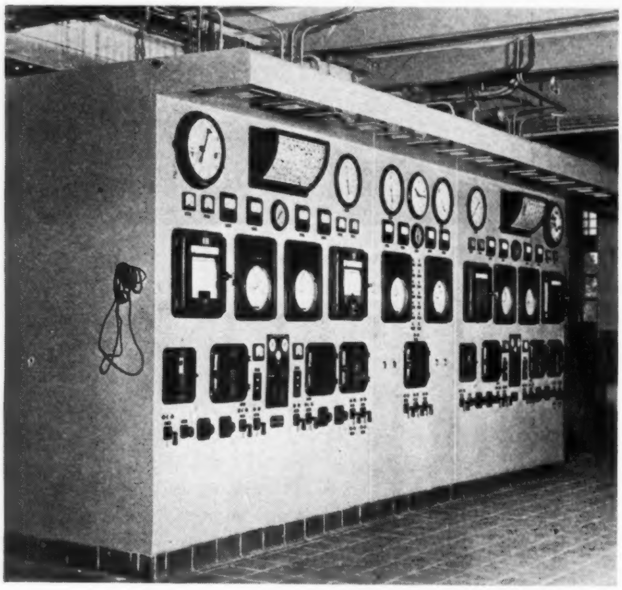


Fig. 5—View of control board

In burning small sizes of anthracite, considerable quantities of fine and extremely abrasive particles are carried in suspension by the combustion gases through the boiler and heat-recovery equipment. To cope with this collection hoppers have been located at the bottom of the first and last boiler passes and a Western Precipitation "Multiclone" dust collector is installed at the boiler outlet ahead of the economizer, air heater, and induced-draft fan. Due to the relatively high percentage of carbon present in the material collected in the hoppers, in the boiler passes, and at the Multiclone, arrangements have been made to return it to the stoker for reburning. Therefore, a separate fan, taking air from the room is employed to transport the material and blow it through the rear wall above the stoker. Rotary feeders are installed for continuous removal of cinders from the dust collector and at the same time provide a seal to prevent bypassing of furnace gases. The hoppers in the boiler passes are emptied continuously by gravity.

Ash is continuously discharged over the end of the traveling grate to an Allen-Sherman-Hoff sectional cast-iron ash hopper arranged for water quenching. This hopper is provided with an auxiliary sump from which the ash is discharged periodically by means of a "Hydroseal" pump directly to fill.

Each boiler is served by a Sturtevant forced-draft fan, driven by a constant-speed motor and equipped with vane control to regulate air flow to the stoker windbox. A single induced-draft fan of Sturtevant design also serves each boiler. These fans are of the paddle-wheel type, operating at a maximum speed of 550 rpm and each is driven by a constant-speed motor through a variable-speed magnetic coupling having a 6-to-1 speed range. Removable liners are provided for the wheel blades and for the scroll. These extend one foot up the side sheets of the casings. The induced-draft fans discharge the gases from boilers to a single 11 ft inside diameter radial-red brick chimney 150 ft high.

The L & N combustion control equipment controls the speed of the stoker and induced-draft fan to maintain the desired steam pressure and fuel-air ratio. The furnace draft is regulated by varying the position of the vanes on the forced-draft fan. The various component units can be operated full automatic (automatic adjustments of all components on both boilers from variations of steam pressure), semi-automatic (boiler manual-automatic adjustments of all components on each boiler by a single control) or hand control (independent control of each element from the boiler board). The steam temperature is controlled automatically by positioning the two by-pass dampers in response to a temperature element in the superheater outlet. Remote manual control is available at the boiler board to position the damper in the over-fire air duct and in the induced-draft fan for shutoff and emergency conditions. Bailey boiler meters are also included on the boiler board as well as a complete complement of draft and pressure gages, and temperature and flow recorders. Draft gages to indicate the air pressure at the various stoker compartments are located adjacent to the compartment dampers.

Coal-Handling System

Coal is supplied to each stoker from an elevated coal storage bunker of 350 tons capacity, of reinforced concrete. The bunker was designed from observations made on a working model built and tested to provide 100 per cent active storage and the elimination of coal hanging up at any point.

Coal is delivered direct from the mines by railroad cars to a track hopper with sufficient capacity for an entire 70-ton car. This track hopper is located at one end of a car-thawing building capable of accommodating four 50-ton cars. A gasoline-engine-driven locomotive is avail-

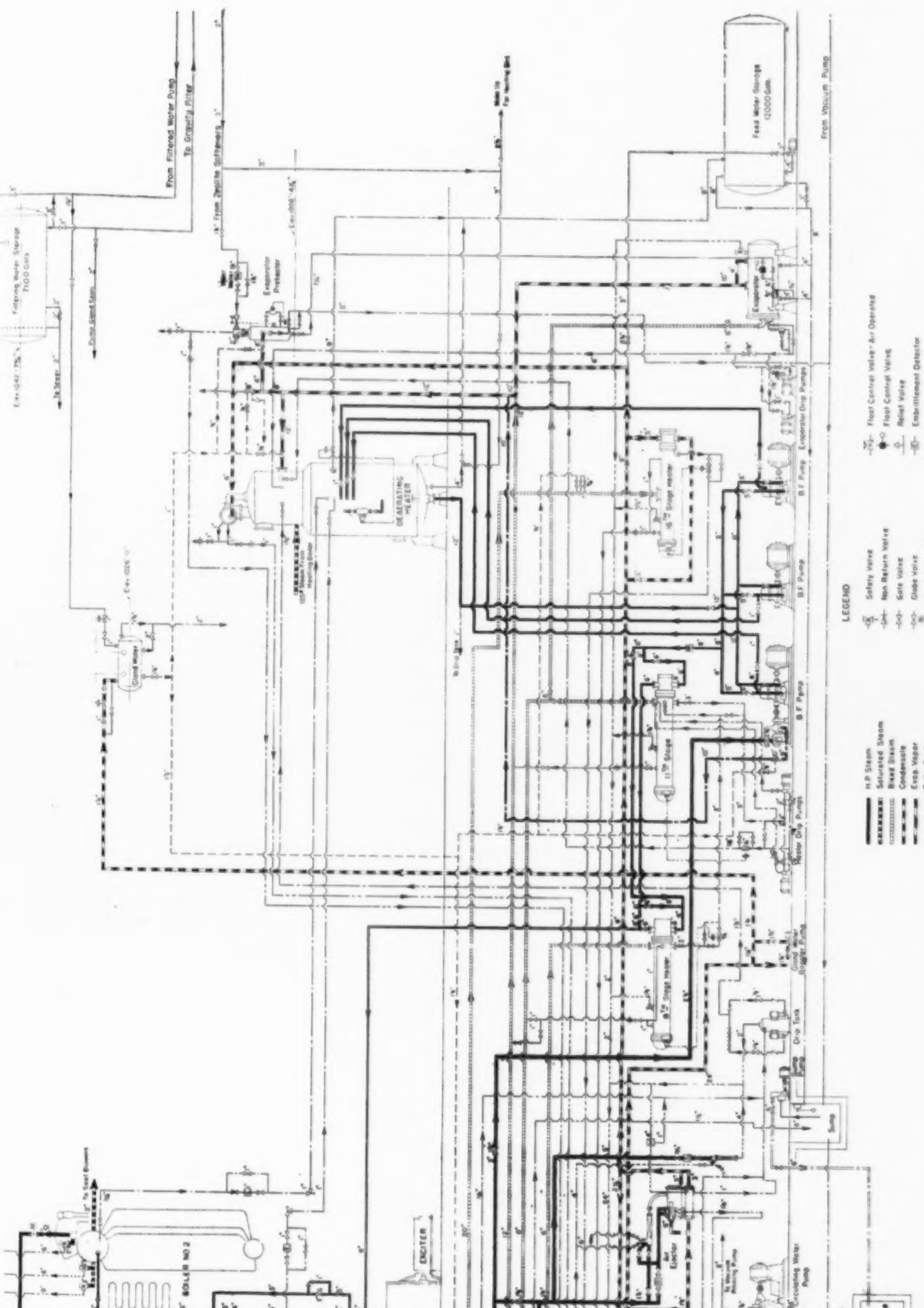


Fig. 6—Mechanical flow diagram of Jennison Station

able to shift the cars as may be required. The coal-handling equipment, with a capcity of 100 tons per hour, was furnished by the Link Belt Company and functions as follows:

Reciprocating feeders convey the coal from the track hopper to an inclined belt conveyor, No. 1. A reciprocating feeder takes coal from the reclaim hopper and, together with No. 1 conveyor, discharges the coal to the No. 2 inclined belt conveyor. A Merrick weightometer weights all the coal passing over this belt and a running record can be kept to show the weight of all the coal received, coal conveyed to the bunkers, coal sent to the outside storage, and coal reclaimed from outside storage. No. 2 belt conveyor discharges the coal into the boot of a single-strand vertical, centrifugal-discharge, bucket elevator which raises the coal and either discharges it through a chute to outside storage or to No. 3 inclined belt conveyor. The latter discharges the coal into an 18-in. diameter screw conveyor made up of sectional flights, the screw revolving in a concrete trough above the coal bunkers. Rack-and-pinion type slide gates are installed in the bottom of the trough to regulate the discharge to the bunkers below. A bulldozer is used to stock out and reclaim coal from storage.

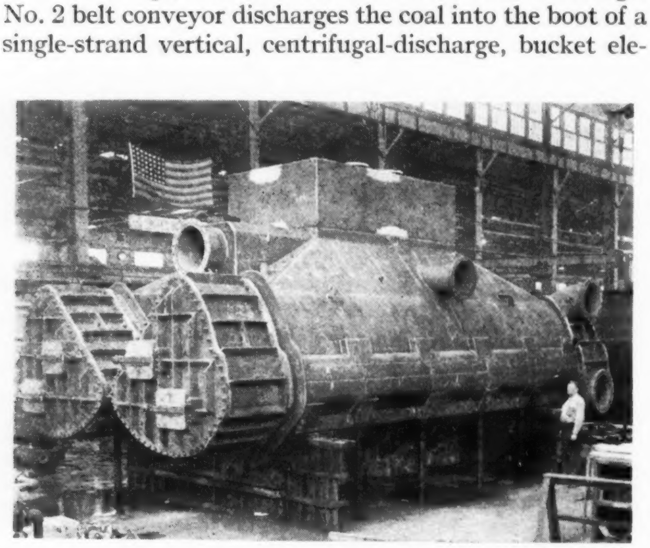


Fig. 7—The condenser is of welded plate construction and in two halves

Main Turbine-Generator

A General Electric single-casing, 18-stage, 3600-rpm impulse condensing turbine is direct-connected to a 30,000-kw, 0.8 power factor, hydrogen-cooled generator designed for $^1/_2$ to 15 pounds pressure. Steam is extracted from the 8th, 11th, 14th and 16th stages. Condensate from the hotwell of the main condenser is pumped first through the inter-after condenser, then through the 16th-stage heater and finally to the deaerating heater by means of the condensate pumps. The deaerating heater is supplied with steam from the 14th stage of the turbine and operates at a pressure varying with the turbine load. Drips from the 8th-stage heater cascade to the 11th-stage heater; those from the 11th-stage heater are returned to the main deaerating heater; and those from the 16th-stage heater are returned to the main condenser hotwell.

The deaerating heater supplies water to the suction of the Ingersoll-Rand, six-stage, opposed-impeller, centrifugal boiler-feed pumps. Two of these pumps are motor-driven and the third is arranged for dual drive. The turbine driving this unit is direct-connected to the pump through a Rawson coupling so that the turbine will stand at rest when the pump is driven by its motor. These pumps discharge the boiler feedwater through the two high-pressure heaters where heat is added from steam extracted from the 11th and 8th stages of the turbine. A feedwater recirculating line from the boiler feed pump to the deaerating heater is also provided.

A Griscom-Russell evaporator of the horizontal bent-tube, submerged type floats on the 11th-stage extraction line. A deaerating preheater operating at the same pressure as the main deaerating heater supplies the makeup to the evaporator which is estimated to be approximately one per cent. Vapor from the evaporator is employed to heat the makeup water in the preheater and to also supply the makeup to the main deaerating heater.

Condenser

The 23,000-sq ft surface condenser, of Ingersoll-Rand design is a twin, two-pass, horizontal unit made of welded steel plate, with divided cast-iron water boxes, muntz metal tube sheets and admiralty tubes. Each condenser half was tubed in the fabricator's shop prior to shipping to the field (see Fig. 7). The condenser is supported mainly on spring supports but partially by the turbine exhaust end to which it is directly bolted. It has a built-in atmospheric relief valve. A cross-over line is provided so that one pump can supply water to both halves of the condenser. Two reversing valves are furnished to permit reversal of circulating water flow to back-wash the tube sheets. Two full-size, four-stage vertical condensate pumps and two one-half size single-stage, horizontal circulating water pumps were also installed. Elimination of a condenser pit in the turbine room basement was accomplished by use of the twin design condenser and vertical condensate pumps.

Two six-foot square concrete circulating water tunnels parallel each other between the turbine room and the screen house, one for the intake and the other for the discharge water. A six-foot diameter concrete pipe connects to the discharge tunnel at the screen house and discharges the water to the river 400 ft down stream. A 30-in. recirculation line is provided to permit use of condenser discharge water to thaw ice forming at the screen house intake. Two Chain Belt traveling screens are installed in the screen house to remove debris from the circulating water, and provision has been made to install mechanical rakes in the future, if found desirable. A Wallace & Tiernan chlorine control installation was made to condition all water entering the screen house. Sluice gates are provided so that water in either half of the screen house intake or the intake tunnel itself can be pumped out to permit inspection or repairs.

Two shallow-well pumps supply all filtered water, water for sanitary uses, and boiler feed makeup. The water for sanitary purposes passes through a sterilizer before use while the plant makeup water passes through a zeolite softener. House service water is obtained from the river through the intake tunnel and provides an emergency source in case the wells fail to produce. When the river water is used in place of the well water, it passes through a Graver Tank primary water-conditioning installation consisting of settling, mixing and

flocculating tanks, gravity filters and the softeners referred to above.

Electrical Features

The generator is connected to a 40,000-kva bank of three single-phase, oil-insulated, 3-winding G.E. transformers, stepping up the generator voltage of 13,800 to 46,000 and 114,000 volts. This transformer bank is protected from fire by a "Fire Fog" installation. The station service transformers of 13,800 to 2300 volts, 2300 to 440 volts, and 2300 to 120/208 volts are located in the basement. These transformers are three-phase, self-cooled, and pyronal insulated. An auxiliary source of station service power is obtained from a 46,000/2300-volt, three-phase transformer located at the 46-kv substation. An automatic throwover from the main to the auxiliary source is provided.

Aluminum is used throughout for the generator leads and substation buses.

The main switchboard in the control room is of tunnel-type construction and provides complete control of the generator, all transmission lines and station service buses.

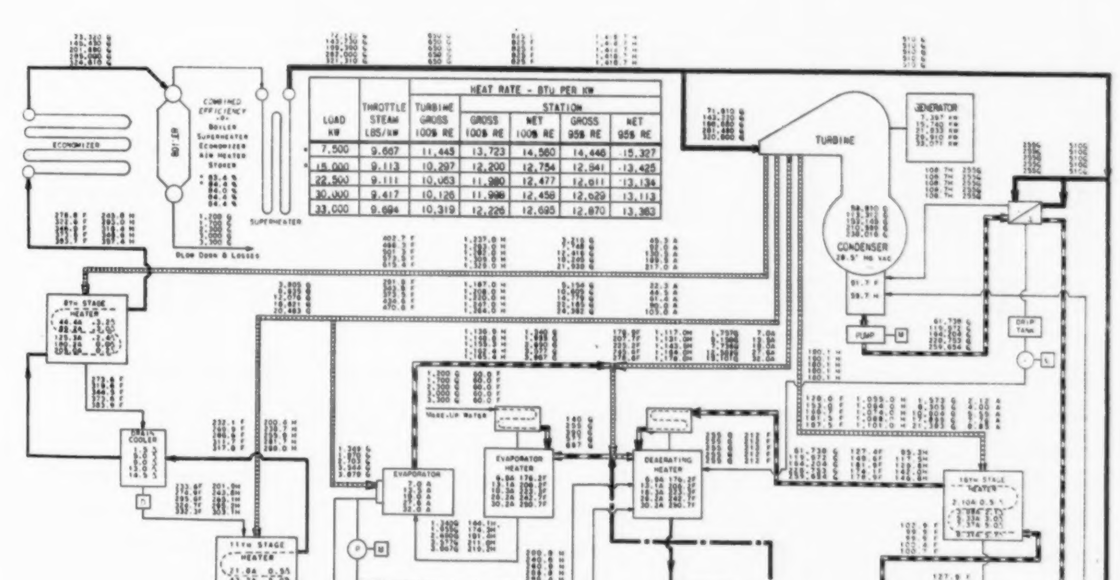
There are three motor voltages used in the plant, essentially divided as follows: motors 100 hp and above, 2300 volts; motors 5 to 75 hp, 440 volts; and all motors less than 5 hp, 208 volts. All the 2300- and 440-volt motor circuits have thermal relays to provide alarms on overload and induction-type relays for locked rotor and short-circuit protection. All motors, with but few exceptions, are Westinghouse standard squirrel-cage induction, drip-proof construction, cross-the-line starting, class A special No. 1 insulation, with sleeve bearings. The larger motors have split end bells.

All circuit-breakers within the plant are of the air type and all outdoor oil circuit-breakers are pneumatically operated.

The 13,800-volt switchgear is of the cubicle type with compressed-air breakers. The 2300-volt switchgear, also of Westinghouse design is of the metal-clad type with De-ion air circuit-breakers. The switchgear for 440 and 208/120 volts is the multumite, drawout unit ITE type.

Two RCA paging systems are installed. One covers the coal-handling facilities from the track hopper house through the coal tunnel up to the conveyor floor above the coal bunkers. The other covers the remainder of the plant with microphones and loud speaker located throughout, including the offices, locker room, machine shop, etc.

The turbine-generator was started on test in the early part of October and a formal opening date of December 13, 1945, was tentatively set.



LOAD KW	THROTTLE STEAM LBS/KW	HEAT RATE - BTU PER KW: TURBINE GROSS 100% RE	STATION GROSS 100% RE	STATION NET 100% RE	STATION GROSS 95% RE	STATION NET 95% RE
7,500	9.667	11,445	13,723	14,560	14,446	15,327
15,000	9.113	10,297	12,200	12,754	12,841	13,425
22,500	9.111	10,063	11,980	12,477	12,611	13,134
30,000	9.417	10,126	11,988	12,458	12,629	13,113
33,000	9.694	10,319	12,226	12,695	12,870	13,383

Fig. 8—Heat balance diagram

A.S.M.E. ANNUAL MEETING

Among the numerous topics discussed, which are here reviewed, were forced-circulation boilers, a new method of coal pulverization, reducing losses in power generation and consumption, estimating Army fuel consumption, research in the Navy, German synthetic fuels, graphitization of steel piping, rotary pump theory, and locomotive utilization of solid fuels.

DESPITE the short time since the ODT lifted the ban on conventions, the 66th Annual Meeting of The American Society of Mechanical Engineers, November 26–29, had an attendance of nearly 4,000 and included some 60 technical sessions and over 150 papers. A wide variety of subjects was covered, but the following report deals only with a few that were of primary interest to those in the field of steam power.

Forced Circulation

A whole session on Monday evening was given over to four papers dealing with the controlled forced-circulation boiler installed at the Somerset Station of the Montaup Electric Company. These were in the nature of progress reports dealing with operating experience since the unit was placed in regular service late in 1942. Operating history was dealt with in a paper by **G. U. Parks** of the Montaup Electric Company, **W. S. Patterson** of Combustion Engineering Company and **W. F. Ryan** of Stone & Webster Engineering Corporation. Feedwater studies and experience were covered in a paper by **W. D. Bissell** of the Montaup Electric Company, **B. J. Cross** of Combustion Engineering Company and **H. E. White** of Stone & Webster Engineering Corporation. Results of potassium treatment were discussed by **W. W. Cerna** and **R. K. Scott,** both of Hall Laboratories. The fourth paper, by **W. D. Bissell** and **E. B. Powell** of Stone & Webster dealt with instruments and control equipment.

An abstract of these papers will be found elsewhere in this issue.

Comparison of Forced- and Natural-Circulation Boilers

At the Third Power Session on Tuesday afternoon a paper by **George F. Ross** and **Leonard Wilkins,** both of Koppers Company, compared operation of the forced- and natural-circulation boilers installed at the Butadiene-Styrene synthetic rubber plant at Kobuta, Pa.

This plant which started operation in the summer of 1943 contained three 250,000-lb per hr natural-circulation boilers of the two-drum bent-tube type and one single-drum forced-circulation unit of like capacity, all designed for 725 psi, 750 F steam at the superheater outlet. They are fired with pulverized coal and the furnaces have hopper bottoms. The forced-circulation unit employs $1^1/_4$-in. trifurcated wall tubes. To meet additional demands for process steam a fifth boiler was later installed. This was of the four-drum, natural-circulation type designed for 450 psi without superheat.

The four initial boilers supply steam to a 35,000-kw turbine-generator which exhausts at 165 psi to process. The electrical load of the plant approximates 14,000 kw, the excess electrical energy being fed to the local utility system.

Boiler feed is taken from the Ohio River which is subject to wide seasonal variations in hardness and dissolved solids, the latter varying from 100 to over 600 ppm. It is filtered and then treated in zeolite softeners. On the basis of an average analysis of 178 ppm dissolved solids a 10 per cent blowdown was expected; but at times when the dissolved solids increased to over 600 ppm it became necessary to employ 30 per cent blowdown. Moreover, due to the requirements and the nature of the process, from 60 to 70 per cent makeup is necessary.

Inasmuch as the forced-circulation boiler contains about 37,000 lb of water at steaming level compared to 155,000 lb in the natural-circulation boilers, the former is more sensitive to changes in feedwater conditions at times of high solids content. Operating data indicate that the natural-circulation boilers can be run at 400,000 lb per hr with 4000 ppm dissolved solids in the boiler water, whereas in the forced-circulation boiler, operating at this output, the concentrating effect of evaporation would result in a total dissolved solids content of 9600 ppm.

With the high makeup previously mentioned, and with the necessity of keeping the boilers on the line for long periods, it has been observed that the natural-circulation units acquire considerable sludge in the vicinity of the downcomer tubes at the top drum. In the forced-circulation unit, this sludge with additional scale particles, collects on the orifice strainers and tends to plug the orifices. On two occasions this plugging resulted in tube failure. Removal of the sludge in the natural-circulation units is accomplished by turbining the tubes every 6 months, whereas with the forced-circulation unit sludge and scale removal is accomplished by removing and cleaning the orifice strainers. For this purpose it has been deemed advisable to shut down the unit every 60 days to inspect these parts.

The desirability of preventing sludge accumulations in both types of boilers has led all concerned to the conclusion that the problem is one of chemical treatment.

The forced- and natural-circulation units are consistently operated at 85 per cent efficiency and steam requirements of the circulating pumps serving the former are approximately 3 per cent of the boiler capacity.

With the chemical process unable to reduce the steam demand at short notice, the forced-circulation boiler, in the case of a wall-tube rupture was kept on the line at full rating for over 3 hr.

Summarizing the advantages and disadvantages of the two types of boilers, based on experience at Kobuta, the authors arrived at the conclusions listed.

The forced-circulation unit has demonstrated particular operating assets as follows:

1. The ability to suffer loss of a tube and continue to operate until other apparatus is brought on the line

to take its place, or until load can be sufficiently reduced so that boiler capacity is not required.

2. Water-level stability under conditions of rapid and large load changes.

The natural-circulation units have particular operating assets as follows:

1. Greater availability in comparison with the forced-circulation type.
2. Less sensitivity to changes in feedwater conditions, rendering it more suitable for high make-up with high solids in the feedwater.
3. Lower susceptibility to scale formation under equivalent feedwater conditions.

Discussion

In discussing this paper, **W. S. Patterson** pointed out certain design features of the forced-circulation unit not included in the paper. For instance, the employment of small-diameter tubes produces a high flow resistance and high velocity which is desirable because the high fluid velocity in the tubes can be realized with a minimum quantity of circulating water handled by the pumps. These small-diameter tubes have thin walls which result in low hot-face skin temperatures and low temperature stress in the tube metal, regardless of the rate of heat absorption. There is also a saving in weight of tube metal and weight of water in the tubes. Use of trifurcated tubes decreases the number of header connections, orifices and access openings.

A comparison of data in the paper shows that the forced-circulation boiler has only 14,340 sq ft of surface between the superheater and the air heater compared to 20,640 sq ft for the natural-circulation units, despite the fact that a large part of this surface in the former includes fins. Nevertheless, there is a difference in draft loss in favor of the forced-circulation unit which would exceed 4 in. wg when corrected to the same steam output and Co_2. Also, since the steam drum is not required to support a bank of generating tubes, it is located entirely outside the setting and thus does away with the necessity of providing drum protection.

The low weight of water is associated with a low weight of tube metal and this combination results in a lower fuel requirement to place a forced-circulation boiler in service and less heat loss in cooling down, which is a distinct asset in the case of a boiler subject to week-end shutdowns as is the case with many industrial plants.

Moreover, with the increasing popularity of acid cleaning of boilers it is an operating asset to require only one-quarter of the amount of acid, flushing water and neutralizing solution, as well as a saving in time.

While the paper mentioned that 10,000 lb of steam per hour is required for the circulating pump drives, Mr. Patterson pointed out that the heat extracted in the turbine is only about 200 Btu per lb or 2,000,000 Btu per hr. The fuel equivalent of this is about 0.50 per cent of the fuel fired at maximum rated capacity and part of this energy is returned to the boiler water in passing through the pump. The lower inherent efficiency from this cause is offset by the lower induced-draft fan power indicated in the paper.

As to the availability of this unit, the discussor added that it had been definitely recommended by the boiler manufacturer that the unit be taken out of service every sixty days for inspection as this was a new development and it was felt that frequent inspections would avoid the possibility of forced outage.

New Method of Coal Pulverization

A new method of pulverizing and drying coal, similar in principle to that used in "puffing" cereals, was described in a paper by **J. I. Yellott,** Director of Research for the Locomotive Development Committee of Bituminous Coal Research, Inc. and **A. D. Singh,** Supervisor of the Coal and Gasification Section, Institute of Gas Technology, Chicago. Mr. Yellott explained the process with the aid of slides. It is still in the experimental stage at the Johns Hopkins University. Briefly the method is as follows:

Coal, crushed to pass through a 16-mesh screen is fed by a screw to the entrance to a nozzle where it is met by a stream of superheated steam. The steam permeates the coal and upon leaving the nozzle the release in pressure causes the coal particles to explode to form a fine dry powder. Passage through the nozzle is almost instantaneous. The drop in pressure is very rapid and the coal is collected in a cyclone, or a classifier may be used. Fineness of pulverization is a function of the initial pressure. With 100 psi steam pressure the coal is pulverized so that approximately 60 per cent will pass through a 200 mesh. The larger particles from the classifier are recycled. Moreover, coal of 6 to 8 per cent moisture, in passing through the nozzle, is dried to about 1 per cent moisture, the drying effect being similar to that in a throttling calorimeter.

Inasmuch as higher steam pressures have not been available in the laboratory, tests so far have been conducted at 100 psi. With this pressure 0.5 to 0.7 lb of steam per pound of coal seems to give the most effective pulverization, but these figures may be reduced with higher pressures. A $^1/_2$-in. nozzle will pass a ton of coal per hour. For experimental purposes a plastic nozzle has been employed for ease of observation. Furthermore, it has been discovered that the nozzle need not be circular; a square nozzle is equally effective.

The process has been found well adapted to pulverizing coke breeze, but with oil shale it does not respond well. Very little abrasion of the nozzle is observed with bituminous coal.

Tests with Compressed Air

Tests have also been conducted with compressed air in place of steam and have proved equally effective without heating the air. With air, some sparks have been observed but the speed in passing through the nozzle appears to be sufficiently great to avoid ignition.

The process seems to be particularly well adapted to the preparation of coal for burning in the open-cycle gas turbine. In such application, the coal would be put under pressure and the air at about 60 psi for pulverizing would be obtained from an auxiliary compressor which would take its air from the discharge of the main compressor. The pulverizing air would then serve as primary air to convey the pulverized coal into the chamber. About 1 per cent of the net output of the gas turbine would be required to drive the auxiliary compressor.

Reducing Losses in Power Generation and Consumption

While practice varies widely among different companies as to methods of checking performance and carrying on plant betterment work, a cross-section of such methods, as applied to large and medium-size industrial plants, oil refineries, central stations and marine installations, was afforded by a symposium on the subject at the Wednesday evening session, sponsored by the Power and Fuels Divisions.

The procedure employed by E. I. du Pont de Nemours & Company for a group of relatively large plants was reviewed by **H. D. Harkins** of that company; that practiced by the Forstmann Woolen Company, covering two closely integrated plants of medium size in the textile industry was explained by **Frank L. Bradley,** its plant engineer; the problems peculiar to operation of an oil refinery plant were discussed by O. F. Campbell, combustion engineer of the Sinclair Refining Company; the organization for supervisory control of such matters in the generating stations of the Commonwealth Edison Company, Chicago, was described by **J. R. Michel,** mechanical assistant to the superintendent of generating stations; and **L. M. Goldsmith** chief engineer of the Atlantic Refining Company, told of the economic operation of a fleet of large high-speed, high-pressure, turbine-electric-driven tankers.

Mr. Harkins pointed out that a large industrial power plant, because of the diversified services furnished, presents a much more complex problem than a central station where overall economy can be measured by the fuel input and the electrical output. The system employed by his organization is based on a comparison of actual results with standard fuel consumption computed from heat balance analysis. The ratio of the two provides an index to overall plant performance. He emphasized that plant betterment work must be predicated upon continuance measurements rather than periodic tests and that usually greater savings can be effected in power consumption than in power generation. Proper loading of units, avoidance of unnecessary outages, process improvements and prevention of leaks were listed among the principal items leading to maximum economy. In an organization such as this, involving numerous power plants, a staff of trained men is essential to carry out betterment work.

Mr. Bradley observed that in an industrial power plant, the interest and support of management is influenced to a large extent by the extent to which power and steam costs enter into the production cost of the finished product. In one of his two plants the power demand for spinning greatly exceeds the steam demand, whereas in the other plant the demand for steam used in finishing exceeds the power demand.

He sketched the organization setup. The superintendent of each production department and the plant engineer report directly to the top executives of the company. The engineering group, as well as the steam and power department chief, report to the plant engineer. The chief power clerk collects all operating data and transmits them to the power supervisor. Changes and improvements that do not affect production routine are decided upon among the power supervisor, the power clerk and the plant engineer; whereas any corrective measures that involve operations outside the power house and concern company policy, such as shutdowns, changes in shifts or recess periods, etc., require decisions by the plant engineer in conference with executives. Improvement in manufacturing methods is the responsibility of the design department in cooperation with the plant engineer.

Mr. Campbell explained why a refinery power plant differs materially from those in most process industries. There is always a fire hazard present around a refinery; many of the boilers are placed outdoors with housing for the operators; the petroleum process is one of continual development, and the steam and power services must follow the demands of such development; also the makeup is necessarily high because the greater part of the steam is used up in process. Due to the continuity of the process it is important that boilers be off the line for minimum periods only, which accounts for employment of acid cleaning. Moreover, it has been common practice to wash turbines with water while running at full speed; and connections to high-pressure steam lines have been made while in service by use of welded collars.

A constant search is made to detect leaks for which purpose the larger refineries maintain a crew of trained waste chasers. There are also instrument men on each shift to inspect, take readings and repair instruments immediately where required. Complete records are maintained of fuel and all conditions affecting the various utilities. It is significant that in the plants under consideration, the fuel consumption per barrel of oil output steadily declined despite the demands of war.

Mr. Michel showed a chart of the operating and supervisory organization for the four central stations in Chicago and mentioned that it is his company's policy to train men in efficiency methods at the same time they are trained to operate; also the interchange of men between the test and the operating departments has been found beneficial. While day-to-day station performance means little, detailed monthly reports of station performance are maintained in which deviations from required performance are pointed out for corrective measures.

Efficiency in the marine field, said **Mr. Goldsmith,** starts in the design end, and both generation and consumption take place within the same cubical. There are few yardsticks with which to gage marine performance.

The fleet of nine tankers, which he specifically discussed, employ 600-psi steam pressure, 920-F total steam temperature and are turbine-electric driven. Boiler steam is employed for the steam-driven auxiliaries, without desuperheating, but many of the auxiliaries are motor-driven. Automatic combustion control is used on the boilers and steam temperature is maintained within 10 deg. Full instrumentation is employed and records are maintained for each boiler and for other equipment. The main turbine is equipped with a flow meter. Charts and other records are turned in to the port engineer at the end of each voyage. These are checked at irregular intervals by the engineering department. Daily water analyses are taken and an outside firm of feed-water consultants is retained. Electrical insulation is tested on all circuits and equipment at the completion of each voyage and recorded, so that

comparisons may show trends toward deterioration before failure occurs. Hence the tanker crew does not include an electrician.

Every effort is made to conserve steam even to the point of substituting air whistles for the common steam whistle, as the latter consumes a large quantity of steam in foggy weather.

Smoke Regulation

In presenting "Example Sections of a Smoke Regulation Ordinance" **J. F. Barkley,** chairman of the Model Smoke Law Committee, which prepared this paper, stated that it would be well to recognize that all differences of opinion relative to a "smoke" ordinance are basically economic. No one desires unclean air; the question is, how clean an air can we afford?

The paper contained a 16-example section including: Definitions; Creation and Organization of the Department of Smoke Regulation; Duties of the Department of S. R.; Establishment of Rules and Regulations; Installation Permits and Operating Permits; Annual Inspection; Schedule of Fees; Emission Prohibited and Standards of Measurement; Fuel and Equipment Dealers; Entrance to Premises; Appeals to Appeal Board; Persons Liable; Prosecutions and Fines; Coordination of Departments; and General Provisions.

The task accomplished by the committee was applauded by speakers who took part in the discussion, though differences of opinion were expressed regarding details. One speaker referred to air pollution as "aerial sewage." Another claimed that domestic smoke constituted the backbone of the nuisance, while yet another postulated that solution of this problem lay in a good educational program and an ordinance that could be enforced. A speaker from Rochester stated that dust was one thing—soot another; and that for the last 30 years Rochester prohibited the emission of soot at all times. Another concurred with Mr. Barkley regarding the deficiencies of the Ringelmann Chart; it was nothing for a scientific society to boast about. He suggested proper burning equipment while another stipulated specified efficiencies for separation equipment. Another regretted that a coal man was not represented on the committee. He claimed that mechanical engineers had failed to develop equipment to burn coal, and that with proper equipment there would be no problem to solve.

The most constructive remarks were made by **L. C. Whiton,** of Prat-Daniel Corporation who suggested that provisions be made to allow time to change unsatisfactory equipment. Large plants could easily afford such changes while in small plants it might constitute a heavy burden on the owners. He stressed the fact that city aldermen would regard the example ordinance as the recommendations of experts, and for this reason, particular attention should be given to differences in fuels in different regions, and to differentiate between large and small plants.

Estimating Army Fuel Consumption

One of the major problems of the Army has been the proper allotment of fuel for space heating and other uses in hundreds of camps throughout the United States; a problem complicated by the use of almost every type of fuel and heating equipment, continual personnel changes, and an exceedingly wide variation in heating demands according to camp locality.

R. E. Biller presented an interesting study of this problem made by the Office of the Chief of Engineers of the U. S. Army. The University of Illinois provided consultation service and the U. S. Weather Bureau supplied the necessary weather information. The broad purposes of the study were: (1) to provide a simple, yet accurate, method whereby the post engineers at new and rapidly expanding posts, camps, and stations might estimate annual coal and oil requirements, and (2) to provide a sound, defensible basis for War Department estimates.

A base temperature of 65 F was accepted for calculating degree-days and fuel requirements correlated with degree-days calculated from this base. From curves plotted for four widely separated posts, it was found that fuel consumption did not increase proportionately with increases in the degree-days for the week, and that relatively less coal was used per degree-day in severe weather.

Another objective of the study was to establish, for the various types of buildings, a constant designated as the "Space Heat Factor" (SHF) or the pounds of standard fuel (12,500 Btu) per 1000 sq ft of floor area per degree-day. Actual data indicated that, for any given post, the space heat factor decreased as the weather became more severe. A given type of building located in a mild southern climate used relatively more fuel per degree-day than a similar building located in a colder zone. Climate and other factors also entered into the simplified method.

The average annual per capita consumption ranged between 0.72 tons for 0-degree-day localities to 3.25 tons for 7000-degree-day localities. Comparison of allowance data and actual consumption indicates the accuracy of the original estimates based on the measured fuel consumption at buildings which housed 5000 men, or approximately one per cent of the continental troop strength of the U. S. Army.

Research in the Navy

One of several speakers at the session on Research for National Security was **Rear Admiral H. S. Bowen,** Director of Research and Invention, U. S. Navy. He reviewed the research setup of the Navy which comprises several experimental stations as well as the Boiler Laboratory at Philadelphia, together with a number of cooperating industrial and university laboratories. There has been set up a Research and Invention Division, attached to the Secretary's Office, which contracts for outside research and supervises research being carried on under the several bureaus. It also includes a Technical Library, the function of which is to keep the Navy Department informed as to new ideas and processes.

Prior to the war, the Navy had put into effect a marked increase in steam pressure and temperature on all important vessels of the fleet, standardizing on 600 psi, 850 F total steam temperature. In special cases still higher steam conditions were employed, one destroyer having operated throughout the war with steam at 1300 psi, 925 F. Turbine speeds were increased to

10,000 rpm; alternating current replaced direct current; and carbon-molybdenum steel replaced carbon steel for piping. So far the Navy had not seen fit to adopt automatic combustion control.

With reference to economy in fuel consumption, the speaker referred to the often-expressed comment that full load economy is not as important in naval vessels as that at ordinary cruising speeds. However, during the war most of the vessels operated at high speed over long distances, hence fuel economy at such loads was most important in increasing their radius of action. This fully justified the higher pressures and temperatures employed. Moreover, machinery repairs, other than those incurred in action, were small.

Looking to the future, Admiral Bowen, believed the gas turbine would exert a profound influence on progress. A vast amount of research and money would be involved, but it would probably be necessary to discard many of our old concepts. He believed electronics would find an important place in future developments.

As to atomic energy, he was of the opinion that further research and development would prove too expensive for commercial purposes but not too expensive for naval application. He lamented the fact that withdrawal of scientific students for the armed services had created a marked deficit in men for such work.

German Synthetic Liquid Fuels

Dr. W. C. Schroeder, of the U. S. Bureau of Mines, who headed a group of fuel specialists sent to Germany in the wake of the advancing army to investigate German practice in synthetic liquid fuel production, told of what had been observed.

By the time the mission arrived, about three months before V-E Day, allied bombing had put the Nazi fuel-oil and gasoline plants practically out of service and forced the remaining ones underground, thus paralyzing German rail and motor transport, as well as rendering military aviation relatively impotent.

German synthetic oil production had reached a peak of over 350,000 metric tons per month in 1944 before the bombings became so severe about the middle of that year. Following bombing raids production dropped rapidly, but during subsequent bad weather, which forced reduction in bombing operations, repairs were made and production again picked up until the end of 1944. The Germans had a vast organization of several hundred workers, both German and slave laborers, and high priority for materials in making necessary repairs to such plants; but as repair crews were observed to become smaller and buildings began to assume their normal shape, intensive bombing attacks were repeated. This strategy had a demoralizing effect as well as interfering with production. The Germans then undertook to place synthetic oil plants underground, but at the time the Allied Armies took over, only two underground plants had reached the operating stage of producing any oil.

The investigators found it very difficult to uncover useful information from the ruins of such plants, especially as records of research and development, together with drawings, had been removed and shipped to a supposedly safe location. However, some of these were later discovered hidden in the Herman Goering Iron Mines, south of Brunswick, and other documents in other places. At Reelkirchen, six large rooms in a house were found filled to the ceilings with such documents. Much information was also obtained through interrogation of the Germans who had supervised and operated these plants.

There were 23 engineers in the American group which had its headquarters in London. Reports have thus far been prepared covering their examination of 200,000 pages of German text, which have been brought to the United States in the form of microfilms. The task of translating and abstracting is a formidable one and twenty teams have been organized for this work. When it has been completed the results will be made available to industry.

Graphitization of Steel Piping

Several investigations regarding graphitization in steel piping and cast steels are in progress, and the results of these investigations to date were made available to the Society in six noteworthy papers. It is the intention of the Society to collect and publish these papers in one volume.

The *Summary Report on the Joint E.E.I.-A.E.I.C. Investigation* by **S. L. Hoyt, R. D. Williams** and **A. N. Hall** was an outstanding contribution by the Battelle Memorial Institute. These authors have accumulated data on the influence of deoxidation and the composition of steel, on the effects of welding heat and other preservice heat treatments, and on the influence of microstructure and cold deformation. Results of the study throw some light on the mechanism of graphitization and provide a basis for prescribing the steel to be used and for setting safe operating temperatures.

The deoxidization practice in making steels has a pronounced effect on graphitization, particularly the use of $1^1/_2$ to 2 lb of aluminum per ton in both carbon and carbon-molybdenum steels. Its effect is more pronounced than is the stabilizing effect of 0.5 per cent molybdenum. Steels with not over 0.5 lb per ton and straight silicon-killed steels are found to be relatively immune. These steels showed highly normal case structure in the McQuaid-Ehn test while the same steels deoxidized with the larger amounts of aluminum showed the "abnormal" structure.

Indications to date are that the nongraphitizing steels contain not over 0.01 per cent free carbon and the graphitizing steels about 0.04 per cent. This is an important lead that should be followed up by determining free carbons on new lots of both wrought and cast steels for information purposes.

Manganese and silicon are both known to affect graphitization, but as these elements have been held at fairly constant levels, no specific effects have been uncovered to date.

Molybdenum is known to form a (metallic) carbide and has been shown to exert a stabilizing effect on pipe steels. It also has an effect on the structure of steel and may have a secondary effect of this type. What this might be is not yet known quantitatively.

Chromium also forms a highly stable carbide and is now considered to be the best element to add to carbon and carbon-molybdenum steels to prevent graphitiza-

tion in service. In contrast to molybdenum, the addition of as little as 0.25 per cent chromium has checked graphite in high-aluminum killed steels. However, tests of steels containing 1 per cent or more chromium have shown "traces" of some new substance which occurs in very tiny dark specks.

While random graphitization can occur in these steels without causing undue alarm, the heat effects of welding establish a highly critical zone where the stock has been heated to about the Ac_1 temperature. This is the major cause of segregated graphite.

While stress-relieving temperatures of 1200 to 1300 F retard graphitization, it seems to be necessary to eradicate the structure of the heat-affected zone to have any important effect on the elimination of segregated graphite. Such a stress relieving would be done just above the critical temperature for a long enough time to accomplish this. This treatment should be regarded as a "corrective measure" for use with a known or suspected graphitizable steel, but by no means as a substitute for a stable steel.

Effects of Welding

Welding techniques should be looked for which would ameliorate the structural conditions that invite graphite segregation. The use of a high heat input and preheat which widen the heat-affected zone should be beneficial and should improve the effectiveness of stress relieving above Ac_1.

Prior structure of the part as welded does not appear to have a dominating effect on graphitization. It may have a secondary effect on the susceptible structure set up by welding, but an analysis of its precise effects is far less important than finding a steel which is immune to graphitization and not sensitive to deoxidization, welding, structure, etc.

The effects of cold wood do not enter into the problem in a practical way, but laboratory tests have shown that cold deformation of graphitizable steels accelerates the process.

It is pointed out that the various investigational programs have all related to service temperatures not above the 925 to 950 F mean operating temperature range. Steam temperatures of 1000 F and above would very likely call for a different type of steel.

Suggestions for the Power Industry. (1) For new steam-line installations, it is suggested that a "normal" (low-aluminum- or silicon-killed) carbon-molybdenum steel with initial graphite content of not more than 0.01 per cent, or a chromium-molybdenum steel containing 0.50 to 1.00 per cent chromium and 0.50 per cent molybdenum be used. Also, it appears advisable to stress-relieve these steels above their Ac_1 temperature after welding. Future work may show this to be unnecessary.

(2) Though joints exhibiting some graphitization in service can generally be healed by normalizing at 1650–1700 F, they should be checked periodically.

(3) When a joint is severely graphitized, the only safe procedure is to cut it out and reweld, or replace it with a spool of new pipe. Where severe graphitization is encountered in a large number of joints, it is safest to replace all the pipe with a type resistant to graphitization.

Cast Steels

In summarizing the paper *Graphitization in Some Cast Steels* by **A. J. Smith, John Urban** and **F. W. Bolton** (The Lunkenheimer Company) it was stated that it has not been possible to insure against graphitization through any of the controlled procedures of melting and deoxidization practice and heat treatment. Indications are that freedom from graphitization is to be sought through the use of alloy additions which confer greater stability to the carbide and probably to lessen migration in the ferrite. Cases cited of low alloy chrome-molybdenum steel at conventional service temperatures offer little assurance of freedom from graphitization by the use of such low chromium additions to the moly steels alone. Extensive experimental data lead to such assurance for the nickel chrome moly steels within the specification range of A.S.T.M. A-217-WC-4. In no case has graphitization been found in the nickel-chrome-moly steel.

Influence of Heat Treatment

The paper presented by **F. Eberle** (Babcock & Wilcox Company) dealt with the *Influence of Heat Treatment Upon the Susceptibility to Graphitization of High Aluminum Deoxidized Carbon-Molybdenum Steel.* He outlined experimental procedures on unwelded specimens, spot welds and multiple pass arc welds, and evaluated the results of twelve different tests. General deductions derived from these tests suggested the following practical conclusions:

(1) Normalized material is slightly less susceptible to graphitization than annealed material.

(2) Normalizing at temperatures close to the A_3 point offers a better safeguard against the formation of dangerous chain graphite than normalizing at very high temperatures.

(3) Welding conditions should be chosen so as to minimize strain in the weld-affected metal by suitable preheating.

(4) Long-time stress relieving at 1300 F is more advantageous as a safeguard against graphitization than conventional stress relieving at 1200 F.

Rotary Pump Theory

A Theory of Rotary Pumps and Fluid Motors was the subject of a paper given by **Warren E. Wilson** of Armour Research Foundation. The theory presented described the performance of rotary positive displacement pumps and motors in terms of torque and capacity. From the equations of these two qualities, expressions for power input, power output and efficiency were developed. It was shown that, under certain specified conditions, the maximum efficiency which may be attained with any given pump or motor is independent of the viscosity of the fluid or operating pressure (head) and is determined by the physical dimensions and characteristics of the unit only.

The equations developed apply to a rotary displacement unit acting as a pump or as a motor. The definite volume of fluid trapped between the rotary element and the housing is positively forced through the unit. Viscous, bearing and gear friction and other mechanical effects tend to resist motion of the rotor. These result

in a change in the shaft torque which is termed "torque loss." Flow through the clearances and seals causes an actual discharge differing from the theoretical discharge. These secondary flows are referred to collectively as "slip."

Two types of fluid flow in the unit are recognized: (1) Laminar flow throughout the unit giving a viscous torque resistance proportional to the first power of the angular speed and first power of the viscosity, and a slip proportional to the first power of the pressure difference and inversely proportional to the viscosity. (2) All flow in the unit in the turbulent range giving a torque resistance proportional to the square of the angular speed and slip proportional to the square root of the pressure difference. Both resistance and slip are independent of the viscosity in this case.

It is assumed that there is no cavitation, no air entrained in the fluid, that the shaft is right, clearances remain constant, and that the coefficient of Coulomb friction is a constant.

Equations for torque and capacity for both pump and motor may be written on the basis of the general expressions for torque and discharge given below. The equations refer to a pump if the upper algebraic sign is used; to the motor if the lower sign is used.

$$\text{Torque: } T = \Sigma T_t \pm T_L \pm T_f$$

where T is the actual torque; T_t is the theoretical torque due to the pressure difference; T_f is the torque loss due to Coulomb friction which is independent of pressure; T_L is the torque loss due to fluid resistance; and $T_t(1-\Sigma)$ is the torque loss due to friction which is proportional to pressure.

$$\text{Capacity: } Q = Q_t \mp Q_s$$

Where Q is the actual capacity; Q_t is the theoretical capacity; and Q_s is the slip.

Performance charts in dimensionless form were presented and analyzed. Tests of a conventional gear pump operated as a hydraulic motor yielded data which substantiate the theory. Alterations of the physical dimensions of the unit were discussed in terms of effect on the characteristic curves.

On the basis of the experimental data, it was contended that: (1) predictions of the theory are borne out, (2) experimental data may be presented in a very compact dimensionless form; (3) losses in efficiency may be traced readily and the causes determined; (4) hydraulic and mechanical factors in performance are shown in proper perspective and may be analyzed separately; (5) performances of units with fluids giving flows in the turbulent range are expected to be subject to effective study by means of this theory and method of analysis data.

Locomotive Utilization of Solid Fuels

Discussing *Locomotive Fuel from the Coal Man's Viewpoint*, **Carroll F. Hardy** of Appalachian Coals, Inc., contended that one standard size could not be screened out of the coal as mined to meet U. S. railroad needs without changing the sizes of coal furnished to all other coal users. Mechanical cleaning of coal has been developed to a greater extent in some districts and has resulted in a greater proportion of the locomotive fuel being cleaned. The trend is in the direction of more careful sizing and cleaning but all coal mines cannot be changed over immediately to produce a standard size of locomotive fuel. In view of all the factors involved, extensive tests should be made to determine the best performance under road conditions with as many sizes and qualities of coal as is possible.

A. A. Raymond of N.Y.C.-R.R., dealt with the *Utilization of Coal in the Locomotive* with particular reference to the problems of operation. The introduction of the slag baffle had successfully met the problem of tube sheet slagging. Speaking of coal sizes he said egg coal provided more steam than run-of-mine, and that briquettes improved evaporation 28 per cent. Future developments may include centrifugal firing of pulverized coal and multiple cylinder locomotives with axial drive or turbines.

Ralph A. Sherman presented an interesting paper on the *Supply of Air to Coal-Fired Locomotives.* This was a joint paper, with **W. H. Brown** and **R. B. Engdahl** of the Battelle Memorial Institute as co-authors, presenting a study of the factors affecting draft in the front end, with particular reference to improvement of front-end efficiency by determining the correct ratio of stack and nozzle areas in relation to available back pressure from the cylinders.

Kenneth A. Brown, research consultant, stressed the fact that the report of the National Coal Association indicates the increase in the number of orders for diesel locomotives in relation to steam locomotives. He mentioned one railroad that contemplates complete dieselization—a road which today does not own one diesel locomotive.

These papers were followed by a lively discussion which was dominated largely by John I. Yellott's able presentation of the possibilities of the gas-turbine power plant, which held promise of efficiencies of from 25 to 30 per cent.

Another speaker suggested that pulverized coal manufacturers stipulate fineness between two points, e.g., between 10 and 50 microns. A straight line plot between these points would indicate the characteristics of the pulverizer output.

A considerable number of papers dealt with the gas turbine, particularly with reference to its employment in aviation and in the marine field. Also, **Messrs. Agnew, Hawkins** and **Solberg** reported on the results of research conducted at Purdue University on "Stress-Rupture Characteristics of Various Steels at 1200 F."

The usual honors and awards were conferred at the annual dinner on Tuesday night for outstanding accomplishments in the field of mechanical engineering; also, the conferring of honorary memberships. **President Alex D. Bailey** acted as toastmaster.

At the conclusion of the Meeting the new president, **D. Robert Yarnall,** took over the office for the ensuing year.

Low-pressure Ash-sluicing Systems

By T. H. CARR*

In the following excerpts from a paper by T. H. Carr, Electrical Engineer and Manager of the Bradford Corporation Electricity Dept., given before The Institution of Mechanical Engineers (Great Britain), the author discusses some of the requirements for a successful and economical ash-sluicing system. He gives the results of corrosion tests with ash-system water; discusses pump impeller materials; and includes ash-handling costs in three British power stations.

DISPOSAL of ashes from large-capacity power stations is of importance when it is realized that the quantity to be dealt with may represent from 10 to 20 per cent of the weight of coal consumed.

It is generally recognized that the fundamental problems confronting designers of ash-handling plants are dust nuisance, hot abrasive materials, poisonous gases and corrosive acids. All of these are in turn responsible for the numerous attempts which have been and are still being made to facilitate the handling of the ever-increasing quantities of ash and dust, and make the boiler house basement a more congenial place of employment.

For any ash-handling plant it is generally recognized that the principal requirements are:

1. The plant should be able to handle large clinkers, boiler refuse, soot, dust, etc., with minimum attention from operators.
2. The ever-present feature of abrasion should be rendered ineffective by adoption of equipment designed so that long uninterrupted periods of operation can be obtained with little attention.
3. The plant should deal effectively with hot and wet ashes, and operate with but little noise, and, above all, keep the dust nuisance within desirable limits.
4. Operating and maintenance charges should be kept to a minimum, and reasonable facilities for access during operation and maintenance are essential.
5. The system adopted should, under all conditions of operation, lend itself to the ready disposal of the ash.
6. The plant should have a high rate of handling in order to deal adequately with any sudden change in boiler operating conditions, and consume as little power as possible.
7. The ultimate station capacity should be considered in the early stages of design, and the ash plant employed should permit of extension to meet all future needs.

Low-pressure Systems

The water used for conveying the ash from the boiler outlets to the receiving sump or settling pit is supplied continuously by centrifugal pumps.

There are alternative low-pressure water-sluicing systems, but usually they differ only in so far as reclaiming of the ash from the sump is concerned and may be broadly summarized as follows:

1. System using recirculating water pumps, with telpher and grab for reclamation of ash from sump.
2. System in which the ash is crushed before falling into sluice, with pumps for reclaiming the ash from sump. These pumps may discharge the ash and water into hoppers or direct on to waste land.
3. Similar to (2) with the exception that the ash is not crushed.

Figs. 1, 2 and 3 illustrate, diagrammatically, typical low-pressure ash-handling systems.

The recirculating water pumps and troughs are similar in all three systems, and identical layouts are possible. When an ash crusher is included, it necessitates a higher ash basement unless a central crushing plant is installed.

Probably the most favored method of reclaiming ash from the pumps is by telpher and grab. It is reasonably adaptable to almost any site, and the running and maintenance charges are much less than with pumps.

Pumps for handling both water and ash have been employed, but the repairs and maintenance charges are far in excess of telpher and grab handling. Moreover, where overhead storage hoppers are in use, means must

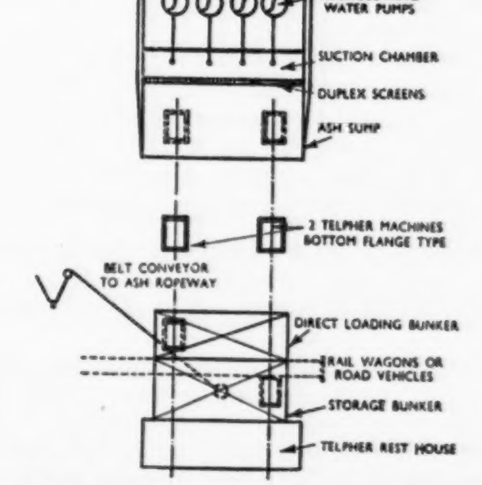


Fig. 1—Layout of ash-handling plant

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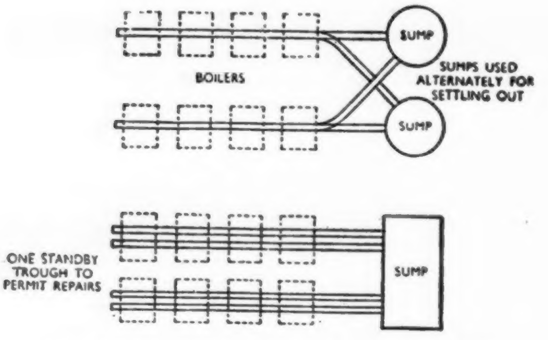

Fig. 2—Alternative sluicing arrangements

be provided for draining the water back to the sump. The crushing of the ash before handling by the pumps does reduce pump wear, but here again the crushing plant must be maintained in good order.

Absence of working parts in contact with the ash is an important feature of the low-pressure ash-sluicing system, since a stream of water running in a specially constructed trough is used as the conveying medium. The ash and water are finally discharged into a sump or settling pit, which is generally situated outside the boiler house.

The settling pit or sump (Fig. 3) is usually one section of a larger pit which is subdivided into three compartments. The first forms a sump into which the ash and water from the boiler house troughs are discharged. The second compartment is the suction chamber, which is connected to the first by way of fixed screens which allow water to pass, but hold up the larger ash screens made up of wedge-shaped steel bars. These bars, which are built up on a frame, have given reasonable service. Duplex screens are sometimes provided to facilitate cleaning and repair without putting the plant out of action.

One type of fixed screen which has been used is of wedge section, made of "Durite" mild steel (0.35 per cent carbon steel), and this has given reasonably good service. It is found that each section—there being four per pump—gives about 500–600 hr, i.e., about one month's service. The bottom screen appears to suffer most, due to the weight of ash imposed upon it, and strengthening frames are necessary. Rotary screens have been used, but repair and maintenance charges have proved heavy.

The continuous water-sluicing system is simple to operate, has low power costs, overcomes dust troubles, and is easily adapted to extension provided the troughs can be accommodated and an adequate fall obtained. Some of the features requiring attention for the satisfactory operation of such systems are as follows:

1. The employment of regular and experienced operatives.
2. Maintenance of correct ash level in the receiving sump.
3. The sump should be as large as possible, with due regard to cost of construction, for there should always be an adequate supply of water in the troughs.
4. Due to the varying nature of the ash, it is well-nigh impossible to provide a trough system which will be entirely trouble-free, particularly with respect to choking. Choking can, however, be reduced to a minimum by providing straight runs of sluicing troughs, together with an adequate supply of water at reasonably high velocity.
5. The trough linings should be maintained in good order to facilitate flow of water-borne ash.

Ash Characteristics

Characteristics of boiler ash vary widely, and the production of large clinker is almost unavoidable when poor coal is burned. The ash is also found to vary according to the method of firing.

With pulverized fuel, 50 to 70 per cent of the total ash appears as dust in the grit arresters and hoppers, and can, therefore, be separated from the ash system if desired. It is the general practice to discharge the flue dust and riddlings into the sluicing system, but experience indicates that this grit is responsible for most of the wear which takes place on the piping and cast-iron pumps. These fines do not settle out in the sump, and appear to be made up of hollow spheres which are able to float; they may even extend to a depth of some 2 ft under the water surface. This sump water is nearly always in a turbulent state, a condition which does not assist settling. Difficulties have even been experienced with the grits that do settle, due to their causing the bulk of the ash in the sump to set hard after a few hours. This makes the task of reclamation by grab buckets more difficult.

Hard clinkers from an ungraded hopper were selected for test, and the average value of three tests gave a figure of 169 lb per cu ft (wet). The weights of dry and wet ash vary considerably; and so far as can be ascertained, wet ash figures of 55 to 75 lb per cu ft are common.

Recirculating Water

In view of the fact that ordinary-grade cast-iron pump bodies and commercial steel and specially hardened steel impellers, were subject to rapid deterioration, in the particular installation under consideration, it was thought that some factor other than abrasion was a con-

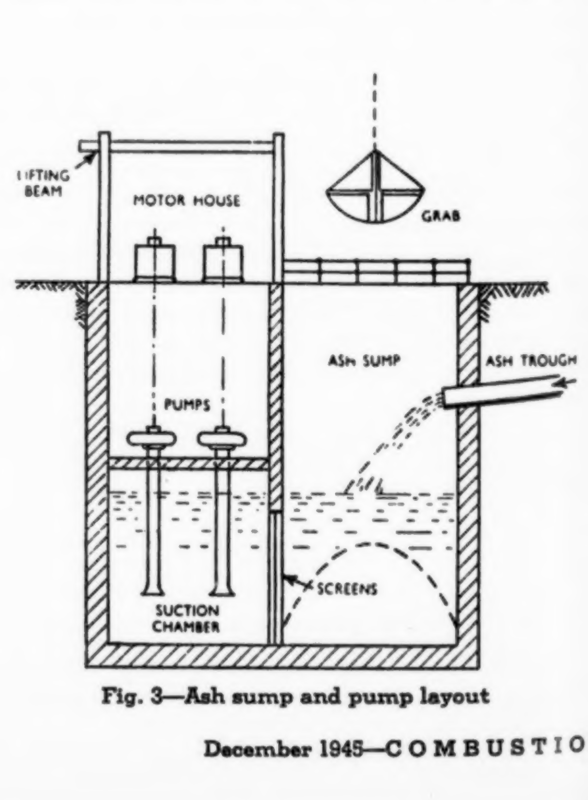

Fig. 3—Ash sump and pump layout

tributory cause of this wear. On the other hand, experience with impellers, valves and other components made of non-ferrous metal (commercial brass) has shown that these are almost immune from attack when working under similar conditions.

To investigate the conditions which influence the loss of metal by corrosion, samples of ash-system water were taken daily for analysis, and controlled corrosion tests were carried out. Table 1 gives the analysis of the ash-system water.

TABLE 1—ASH-SYSTEM WATER ANALYSIS

Date	pH Value	Fe (Parts per Million)	SO_4 (Parts per Million)	Cl (Parts per Million)	Dissolved Solids (Parts per Million)	Lime Required, Lb per 1000 Gal	Remarks
Jan. 15	...	0.7	320	..	...	...	Tests carried out on filtered samples
Jan. 16	8.0	Trace	380	64	800	0.074	
Jan. 17	6.5	5.4	560	11	1350	0.592	
Jan. 18	4.5	1.3	780	27	1100	0.118	
Jan. 19	6.0	2.7	760	28	1600	0.740	
Jan. 20	8.0	0.5	438	36	700	0.060	
Jan. 22	7.5	0.8	503	18	600	0.060	
Jan. 23	6.5	1.1	621	..	950	0.110	
Jan. 24	3.0	9.2	1000	..	1900	3.100	
Jan. 25	3.0	92.2	1529	..	2400	5.120	
Jan. 26	3.0	105.5	1670	..	2400	3.600	
Jan. 27	8.0	25.0	370	..	600	...	
Jan. 31	3.0	...	...	..	2500	2.300	
Feb. 1	3.0	...	...	..	1750	...	

The pH value of the water varies between 8.0 and 3.0, and the water may be alternatively alkaline and acid. The greater part of the sulphate is combined as sodium sulphate, and the iron is present as ferrous iron.

In order to measure the rate of attack as shown by the loss of metal, pieces of ordinary-grade cast iron (percentage analysis: iron, 94; carbon, 3.5; silicon, 2.5) 4 in. $\times 1/2 \times 1/8$ in. were prepared, polished and cleaned. They were then totally immersed in samples of ash-system water, and the iron loss was estimated by the colorimetric determination of iron in the water sample, before and after the test. Table 2 gives the results.

TABLE 2—CORROSION TEST-STAGNANT WATER

Solution Used	pH Value	Conditions in Which Test Was Carried Out	Iron Content of Solutions, G. Before Test	Iron Content of Solutions, G. After Test	Iron Content of Solutions, G. Gain Due to Corrosion	Test Duration, Days	Remarks
Ash sump water	3.0	Stagnant	0.004	0.0135	0.0095	3	
Ash sump water	Greater than 8.3	Stagnant	0.004	0.0115	0.0075	3	Made alkaline by addition of lime
Ash sump water	3.0	Stagnant	0.001	0.0065	0.0055	3	
Ash sump water	Greater than 8.3	Stagnant	0.001	0.0075	0.0065	3	Made alkaline by addition of lime

The tests show that corrosion takes place in acid and alkaline solutions, and it would appear that there is no advantage in making the sump water alkaline. As will be observed, the tests were carried out in a stagnant solution in which the rate of corrosion may gradually diminish and cease.

Further tests were carried out in which the solution was made turbulent by blowing clean air through a sintered glass disk on which the cast-iron strip rested. Table 3 shows the effects of turbulent ash water.

In order to estimate the influence of the pH value of the solution on the corrosion of cast iron, the following synthetic solutions were prepared:

(*a*) Distilled water (electrical conductivity 0.8×10^6 reciprocal ohms) made acid (pH value = 3) by the addition of sulphuric acid.

TABLE 3—CORROSION TEST: TURBULENT WATER

Ordinary-grade Cast Iron

Solution Used	pH Value	Conditions in Which Test Was Carried Out	Iron Content of Solutions, G. Before Test	Iron Content of Solutions, G. After Test	Iron Content of Solutions, G. Gain Due to Corrosion	Test Duration, Days	Remarks
Ash sump water	3.0	Turbulent	0.015	0.032	0.017	1	
Ash sump water	Greater than 8.3	Turbulent	0.015	0.060	0.045	1	Made alkaline by addition of lime

The corrosion was increased; and it is greatest in the solution made alkaline, initially, by the addition of lime.
Ferric hydroxide accumulated on the surface of both strips.

(*b*) Distilled water made alkaline (pH value = 8.3) by the addition of potassium hydroxide.

The results are tabulated in Table 4.

TABLE 4—CORROSION TEST: TURBULENT WATER

Ordinary-grade Cast Iron

Solution Used	pH Value	Conditions in Which Test Was Carried Out	Iron Content of Solutions, G Before Test	Iron Content of Solutions, G After Test	Iron Content of Solutions, G Gain Due to Corrosion	Test Duration, Days
(*a*)	3.0	Turbulent	Nil	0.007	0.007	2
(*b*)	Greater than 8.3	Turbulent	Nil	0.015	0.015	2

The alkaline solution is the more favorable to attack.

A strip of commercial brass (67 per cent copper, 33 per cent zinc), 4 in. $\times$ 1/2 in. $\times$ 1/16 in., was prepared, polished and cleaned, and then totally immersed in a sample of ash sump water made turbulent by blowing clean air through a sintered glass disk on which the strip rested. The results are given in Table 5.

TABLE 5—CORROSION TEST: TURBULENT WATER

Commercial Brass

Solution Used	pH Value	Conditions in Which Test Was Carried Out	Copper Content of Solution, G Before Test	Copper Content of Solution, G After Test	Copper Content of Solution, G Gain Due to Corrosion	Test Duration, Days
Ash sump water	3.0	Turbulent	0.0005	0.0008	0.0003	1

The amount of attack is very small.

Summarizing the result of these tests, it may be concluded that:

1. The filtered ash sump water attacks cast iron in both stagnant and turbulent solutions; this is observed in samples of both alkaline and acid ash sump water, the effect being increased by making the ash sump water alkaline.
2. Commercial brass is also slightly affected by acid turbulent ash sump water.

These tests were carried out on filtered water samples, and the effect of suspended ash particles in promoting loss of metal by abrasion was not considered.

Sluicing Troughs

The troughs may be arranged to receive ashes, riddlings and flue dust; and although the introduction of grits to the troughs overcomes the necessity of providing a separate handling system, it contributes to excessive wear on pumps, valves and pipe lines.

TABLE 6—CORROSION RESISTANCE OF METALS

Solution	Cast Iron Corroded per Sq. M. per Day, G
Standard cast iron	Off scale; so no reading obtained
No. 5 nickel iron, 5 Ni, 0.5 chrome	65
No. 6 nickel iron, 25 per cent nickel iron	25
General-purpose gunmetal, 86 per cent Cu, 8 per cent Sn, 6 per cent Zn	14.7
Phosphor bronze, 86 per cent Cu, 13 per cent Sn, 1 per cent P	12.5
Admiralty gunmetal, 88 per cent Cu, 10 per cent Sn, 2 per cent Zn	10.2

Sample of ash sump water, pH value 5. Test carried out in a "Corrosiometer." Nonferrous metals show considerable advantage over cast iron and cast iron alloyed with additions of nickel. Admiralty gunmetal (88 per cent copper, 10 per cent tin, 2 per cent zinc) is best.

The very abrasive nature of the ash makes it necessary to allow for the insertion of easily renewable liners of semicircular section, made from some form of erosion- and abrasion-resisting iron. These liners are grouted into the troughs, and replacement is effected by chipping out the worn liners and relaying new ones. The liners are in lengths of about 3 ft, and holes are provided to facilitate handling and placing in position.

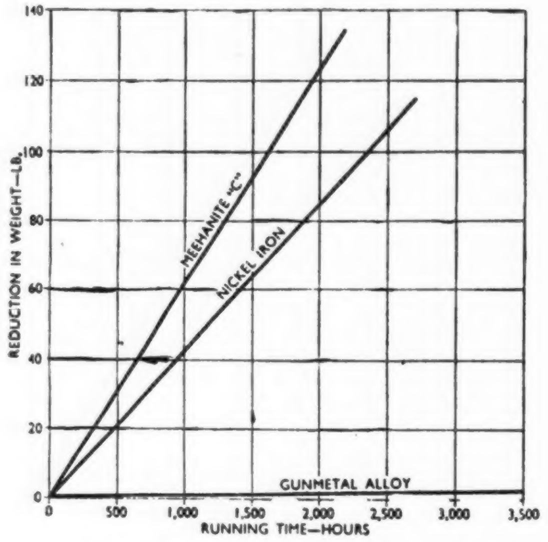

Fig. 4—Rates of wear for impellers of different materials

Where very large clinker is unavoidable and the ash is of high density, it may be necessary to resort to other forms of trough lining materials to withstand the hard wear imposed. In some installations tiling of troughs with hard materials has been carried out.

For chain-grate stoker and pulverized fuel-fired boilers it is usually advisable to cover the troughs with checker plating or concrete slabs, and make them reasonably airtight. Air-sealing plates or doors are sometimes fitted in the troughs between each boiler, but in practice it is found they may give trouble by causing hold-up of the ash, with consequent flooding of the basement.

With boilers having retort-type stokers, it does not appear to be essential to cover the troughs, except as a protection for the workman, for the ash pit apparently restricts free access of air to the boiler, although it may result in damage to the crushing gear due to overheating.

The velocity of the water in the troughs is usually between 10 and 15 ft per sec, and it should be noted that abrasion is minimized with high water velocity, since the ash is caused to ride on the water instead of rolling or sliding along the bottom. Due allowance should always be made for bends and trough junctions when estimating water quantities; otherwise the flow will be insufficient with the consequent choking of the troughs.

It is found that some 1500–2000 gpm of water are required for a 9-in. radius trough, handling about 10 to 15 tons of dry ash per hour on slopes varying from 1 in 60 to 1 in 70, or thereabouts. When using a 12-in. radius trough with a supply of 3500 gpm of water, it is found that some 40 to 60 tons of dry ash per hour can be effectively dealt with on a slope of 1 in 70.

The provision of water jets at trough junctions and bends causes a marked improvement in the handling capacity. Where the main pipe line passes nearby, it is usually convenient to provide a tee in the main line, and to control the supply to one or more jets by means of an isolating valve. These jets are simply tapered pieces of pipe—and are connected to the branch pipe leading from the main line. Flat jets, curved to suit the trough radius, are also useful at junctions.

Pumps

The design and construction of the recirculating water pumps, and their layout, are of prime importance. Experience indicates that horizontal pumps with steam ejector priming are preferable from a maintenance viewpoint. The placing of vertical pumps in a pit is not conducive to easy maintenance unless the pit is adequately proportioned. Leakage is also experienced where the suction pipes enter the sump.

Renewal of pump impellers appears to be a serious matter. Therefore, careful consideration should be given to the material of which they are made. Cast-steel impellers have proved satisfactory, and, as a matter of interest, it may be mentioned that both steel and chilled cast-iron impellers were employed in one installation, and both had approximately the same life, but the latter was only one-quarter of the cost of the former. Gunmetal alloy impellers have also been used in some cases, and have given much better service than those made of other materials. The casings are usually of cast iron and of heavy construction.

The pumps are provided with branches to which a clean water flushing system is connected, one connection being at the stuffing box and the other at the eye of the impeller for the shrouded type. This prevents the access of grit at the eye wearing point, and keeps both the spindle and the impeller free from grit. The fine clearances between the impeller shrouds and the stationary casing are thus sealed with clean water, and further there is always a small leak of clean water inwards, instead of a leak outwards of gritty water at these points.

Various theories have been put forward for the deterioration of cast-iron pump casings and steel impellers, one being that dissolved oxygen in the ash-system water is the main contributory factor, and that gunmetal alloy is to be preferred from a corrosion point of view. Gunmetal alloy impellers, which have given satisfactory service for 9200 and 12,300 hours, respectively, have been put back into operation for continued service.

Fig. 4 shows the rate of wear for three different impeller materials as determined from experience in one plant.

In practice it has been shown that wherever the water is turbulent, or changes direction (i.e., in valves, bends, etc.), wear occurs, and it may be necessary to consider

gunmetal alloy wearing strips on bends and gunmetal alloy valves in order to ensure a reduction in maintenance charges.

Although the first cost of gunmetal alloy pumps is high, the life of such pumps has justified the additional cost. It is reasonable to assume that correspondingly good results would be obtained from the employment of gunmetal alloy valves and bends, or strips on bends of cast-iron piping.

Operation and Maintenance Costs

It is difficult to obtain reliable costs of sluicing plants, for no two station layouts and equipment are alike in every respect; therefore, any figures given must be used with care if a really accurate comparative basis is to be established. Some idea of the costs chargeable to individual sections of plant will be gathered from the following tabulated examples. It is difficult to analyze these accurately, but they suffice to show, despite wide variations in total cost, that similar costs may be expected in certain sections of these plants.

Station A	Cost per Ton of Ash Handled, Pence
Repairs and maintenance:	
Pumps and motors	14.0 (28 cents)
Screening plant (fixed type wedge bar)	2.0 (4 cents)
Telpher	2.6 (5.2 cents)
Troughs	2.3 (4.6 cents)
Storage bunkers (concrete)	0.9 (1.8 cents)
Operation:	
Handling and disposal	18.8 (37.6 cents)
Total cost per ton	40.6 (81.2 cents)
Kwhr consumed per ton of ash handled	20

Station B	Cost per Ton of Ash Handled, Pence
Repairs and maintenance:	
Pumps and motors	1.6 (3.2 cents)
Bunkers and telpher	3.5 (7 cents)
Troughs and sump	4.0 (8 cents)
	9.1 (18.2 cents)
Operation:	
Handling and disposal	31.6 (63.2 cents)
Total cost per ton	40.7 (81.4 cents)
Kwhr consumed per ton of ash handled	25

Station C	Cost per Ton of Ash Handled, Pence
Repairs and maintenance:	
Pumps and motors	2.3 (4.6 cents)
Screens and telpher	7.2 (14.4 cents)
Troughs and sump	1.8 (3.6 cents)
	11.3 (22.6 cents)
Operation:	
Handling	13.0 (26 cents)
Disposal	42.0 (84 cents)
Total cost per ton	66.3 ($1.33)
Kwhr consumed per ton of ash handled	10

The pump costs in station A are very high in comparison with both stations B and C, and this is explained by the fact that the pumps are located in an inaccessible position, and, therefore, do not receive the usual attention. Further, replacement is difficult, and costs are consequently increased. The other sections of plant under "Repairs and maintenance" are reasonably consistent, and so far as operating costs are concerned, the distance and situation of the ash disposal site from the power station are probably the principal factors in incurring high costs. In some cases this disadvantage may be offset by the sale of ash, for which transport is provided free of charge. To improve sales it may be necessary to provide an ash-grading plant.

Experience with 2000-PSI, 960-F Forced-Circulation at Montaup

FOLLOWING are abstracts of the four papers on the Montaup high-pressure controlled forced-circulation boiler given at the recent Annual Meeting of the American Society of Mechanical Engineers, under the auspices of the Power and the Industrial Instruments and Regulators Divisions and the Joint Research Committee on Boiler Feedwater Studies. Because of space limitations these abstracts cover only from a quarter to a third of the contents of the papers which presumably will be available in full at a later date in the *Transactions.*

The first paper of the series enumerates operating experiences and discusses changes and modifications that have been made since the unit was placed in service in 1942. Test results covering circulation, furnace-tube temperatures, steam purity and overall performance of the unit are included.

The second paper presents the results of special studies involving analysis of water and steam at various points between the condenser and the high-pressure turbine, with particular reference to the gradual increase of dissolved iron and hydrogen as the water passes from the hotwell to the boiler.

The third paper discusses briefly the experiences with feedwater treatment of this unit and the control.

The fourth paper reviews the arrangement and functioning of major instruments and controls and discusses the interpretation, operating experiences and incidents justifying the use of these instruments. It also stresses the importance of periodic maintenance and checking.

Operating History and Performance

By G. U. PARKS,* W. S. PATTERSON,† and W. F. RYAN‡

THE forced-circulation boiler at Somerset Station was installed during 1940–42 as part of the topping installation. Initial pressure and temperature were dictated by the necessity of obtaining 25,000 kw by topping a 375-psi 750 F plant. The size and shape of the boiler were determined by the floor space and head room available in a vacant space in the existing boiler room which had been allocated in 1925 to a future boiler of 120,000-lb per hr capacity.

The boiler was guaranteed for a maximum output of 650,000 lb per hr at 960 F at the superheater outlet. Drum safety valves are set to blow at 2000 psi, but average drum pressure over an extended period has not exceeded 1925 psi. Pressure at the superheater outlet averages 1850 psi. The reheater takes exhaust steam from the topping turbine at 400 psi 603 F, and exhausts to the station's low-pressure header at 380 psi 765 F.

The longest outages, which are identified by numbers on Fig. 1, were chargeable to equipment as listed just below the chart. Table 1 supplements this list and shows that there were in the first three years of commercial operation, eight forced outages and forty-six scheduled outages, about half of which were directly chargeable to research and tests and merely consisted of taking the unit off the line for a few hours for checking dissolved and suspended solids in the boiler water. Scheduled outages charged to other equipment were sometimes also used for scheduled boiler maintenance if time permitted. The forced outage in 1944, charged to slag in superheater, was caused by mal-functioning of the air-flow recorder and operation with low excess air.

Although the boiler has been operated in excess of 650,000 lb per hr with both coal and oil firing, output during the past two years was normally limited to approximately 585,000 lb per hr and the average monthly load is under 500,000 lb per hr. This has been for the reasons stated below:

(*a*) Keeping spinning reserve on the system.

(*b*) Large amounts of hydro-generated power which tie lines make available during evening and night.

(*c*) Rebuilding of the 10-in. pressure-reducing and desuperheating station.

(*d*) Vibration and shaft whip in the topping turbine.

(*e*) Inability of the low-pressure plant to absorb more than 500,000 lb per hr when either low-pressure unit is not on the line.

Operating History and Changes

EVAPORATING SURFACE—A furnace-tube failure occurred within the first two months of preliminary operation. A short section of tube was welded in for repair. Microscopic examination indicated overheating.

A second tube failure occurred in January 1943 in the furnace roof in the same tube that had failed previously. This failure was occasioned by pitting on the inside surface of the tube. A large amount of solid deposit found on the inside surface of the tube was considered to be a contributing factor to the corrosion.

The third tube failure occurred in February 1943 in the left side wall. Examination of the failed portion indicated overheating, and the cause was thought to be plugging of one of the orifice strainers.

Each time the boiler had been drained, substantial amounts of foreign matter were found in the orifice headers, particularly near the ends. The boiler had been carefully washed and boiled out, with the orifices and strainers removed, prior to operation and headers were washed at every available opportunity, but the recurrence of foreign particles and substantial amounts of mill scale persisted for some time in the lower headers. There was also evidence of chemical hide-out whenever the boiler was taken off the line.

In order to clean tube surfaces thoroughly and remove mill scale, the boiler was washed with inhibited hydrochloric acid in April 1943. Prior to this time, feedwater was normally treated with

TABLE 1—OUTAGE TABULATION

Reason for Outage	Annual Period Nov. 1 to Nov. 1 1942–43	1943–44	1944–45	3-Yr Period 1942–45
A—Forced Outages				
Furnace Tube Failure	2	1	1	4
Reheater Tube Failure	0	0	2	2
Slag in Superheater	1	1	0	2
Total Forced Outages	3	2	3	8
B—Scheduled Outages				
Research and Tests	7	15	1	23
Piping External to Boiler	2	2	2	6
Low Pressure Station Repairs	0	2	1	3
Pressure Reducing Station	1	0	1	2
Miscellaneous Boiler Items	1	1	0	2
Safety valves	0	0	2	2
High Pressure Turbine	0	1	1	2
Acid Cleaning Boiler	1	0	0	1
Soot Blowers	1	0	0	1
Reheater Repairs	0	0	1	1
Boiler Vent Valve	0	0	1	1
Electrical Trouble	1	0	0	1
Drum Internal Changes	0	1	0	1
Total Scheduled Outages	14	22	10	46
Total Outages	17	24	13	54

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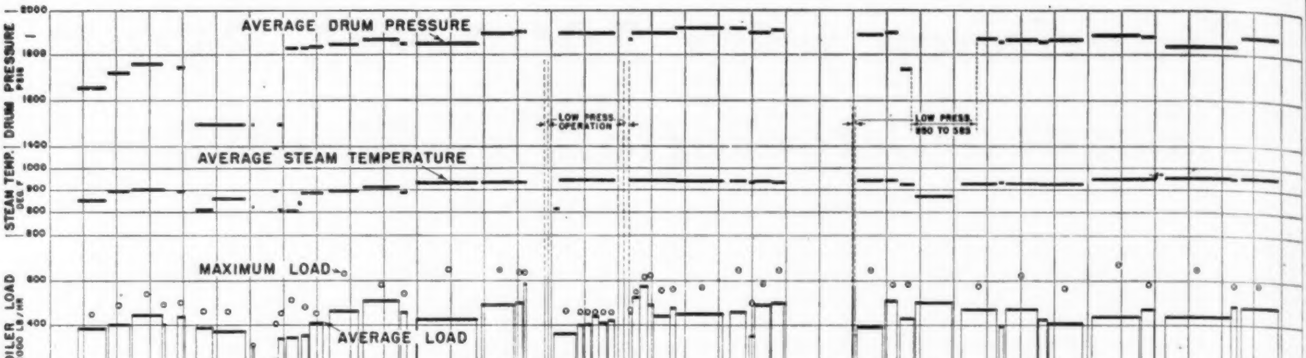

Fig. 1. Load, temperature, pressure and outage chart

1. Furnace tube failure
2. Furnace tube failure
3. Research
4. Acid cleaning
5. Miscellaneous changes
6. Furnace tube failure and acid cleaning
7. Miscellaneous changes
8. Drum internal changes
9. Turbine overhaul
10. Pressure-reducing station
11. Reheater repairs
12. High-pressure turbine

standard sodium chemicals (phosphate, hydroxide and sulphite). After the acid cleaning, the potassium treatment developed by Dr. R. E. Hall was introduced.

In December 1943, after seven months' operation with potassium treatment including silica feed, the fourth tube failure occurred. Failure was considered to be caused by a plugged orifice strainer.

Next, $1^1/_4$-in. circulators were installed between the rear header and the side headers, each provided with a small baffled settling chamber with sampling connections and blow-down valves and upper closure plugs to permit measuring the depth of sludge in the chambers. After establishing the fact that they collected a considerable quantity of sludge, they were connected into the existing drain lines, and are blown down once a week. Since the headers have been interconnected, very little sludge accumulation within them has been evident, and very few of the strainer openings are found closed. In fact, the strainers have not been removed in nearly two years except for inspection purposes.

At the time of the fourth failure, representative tubes were sampled. There were substantial sludge deposits on all of them, and acmite scale on most. Therefore, before the boiler was returned to service, it was again acid cleaned, using inhibited hydrochloric acid, supplemented by a fluoride.

Since this fourth failure, the potassium treatment of feedwater without silica has been used. Tube samples taken in February of 1944, August of 1944 and September of 1945 from several parts of the walls showed very little sludge accumulation, and what did exist was not adherent, but easily brushed away. There was evidence of very little, if any, corrosion or pitting of wall surfaces.

Periodically throughout the three-year operating period the external surfaces of representative furnace tubes have been checked for external corrosion. Although an adherent "enamel" coating of fused slag has been found, similar to that which has been credited with causing corrosion in other furnaces, actual corrosion has been negligible or nonexistent up to October 26, 1945.

On October 26, 1945, about 22 months after the last internal cleaning of the boiler, three small leaks occurred in the rear furnace wall, one located less than a foot above the floor and two about 20 ft above the floor in a different tube. The tubes which had failed were found to be heavily coated with sludge, and on the fire side iron-oxide scale had formed between the sludge and the tube wall, indicating that the sludge had caused overheating.

Before the boiler was again placed in service it was acid cleaned using one circulating pump a few minutes of each hour to maintain uniform solvent temperature throughout the unit.

Superheater and Reheater—There have been no superheater failures, changes or maintenance in either the convection bank or radiant bank.

The steam reheater was provided with bolted ball-and-socket joints where the elements are attached to the headers. On account of numerous leaks during the first two months and the difficulty of access to the joints for refacing it was decided to seal-weld all these joints.

Operation at high rates of output indicated that reheated steam temperatures would be too high at maximum load for continuous operation with carbon-steel reheater elements. It was decided not to reduce the heating surface but rather to correct the difficulty by installation of a manually-controlled steam-atomizing spray-type desuperheater. This was installed between the high-pressure turbine and the reheater in July 1943 and has given satisfactory control.

Economizer—There have been no failures or changes in the economizer.

Drum Internals—The original steam-separating means consisted of a combination of "hydraulic baffle" and metallic baffles in the wet drum and a combination of baffles and rod-type dryer in the dry drum. During the first few months the boiler was sensitive to carryover when the water level approached the centerline of the drum and, because the feedwater regulators were not functioning properly, the capacity was limited to 400,000 lb per hr although higher capacity could have been carried with better water-level regulation. An entirely new set of wet drum internals of the "reversing hood" type was substituted in October 1942.

Although the "reversing hood" steam separators in the wet drum resulted in satisfactory steam purity at loads up to 500,000 it became obvious in June 1943 that further improvements would be necessary to meet the guarantee of 0.50 ppm solids in steam. Furthermore, the gaskets of the drum internals had deteriorated during the acid wash of the boiler in April 1943 so that in August 1943 the wet drum internals were regasketed with copper-covered asbestos, and screen dryers were substituted for the rod dryers in the dry drum. A new set of low velocity screens was later substituted in the dry drum and a perforated baffle plate was installed ahead of each group of steam discharge tubes to produce uniform velocity through the screens. Excellent steam quality is now obtained.

Air Heaters—The air heaters have given excellent service with practically no maintenance. The steam soot blowers have never been used nor have the heaters been washed, although they have been air lanced on three or four occasions.

Soot Blowers—In 1944 the coal was poorer than normal and variable. Slag was sometimes difficult to remove from the furnace walls. The soot blowers in the superheater-reheater zone were badly damaged and it was found that the steam pressure at the high-pressure blowers was considerably below the recommended operating pressure. Since the coal situation might get worse it was decided to review the soot blower situation and take steps toward improvement during the August 1944 annual outage. During overhaul additional bearings were provided for several of the low-pressure elements and replacement elements with larger nozzles were installed between the reheater and front superheater, and wall boxes which

were out of alignment were relocated Operating mechanism of all blowers was overhauled and some changes made. It was found that part of the damage and mal-functioning had been due to lack of lubrication. The effectiveness of the blowers as a whole has been good since this overhaul.

Circulating Pumps—Except for two leaks at the circulating pump heads, these pumps performed satisfactorily during the first three months of preliminary operation but toward the end of October 1942 trouble developed in the labyrinth of one. When the pump was opened up the labyrinth surfaces were found to be badly worn but new parts were installed without any changes except to realign the pump. This pump had another similar failure in November 1942 and toward the end of December 1942 the labyrinth in the second pump failed. New sleeve bearings were installed in both pumps during January 1943 and the bearings of all three pumps were changed to hard babbitt in February 1943. In March 1943 the A pump labyrinth failed for the third time but the trouble was found to be corrosion or erosion of the casing in the labyrinth section. This was repaired by applying stainless steel and remachining. The other two pumps were overhauled during April and May of 1943 and there were no further failures in the labyrinths.

Although there has been no trouble or maintenance on the circulating pumps since the spring of 1943, except oil-pump drive gears, the amount of sealing water used greatly exceeded predictions. In order to operate with closer clearances in the labyrinth, to reduce the sealing water requirements, the pump manufacturer decided to rebuild the bearing body and to substitute roller bearings in place of the babbitted sleeve bearings. The design of the labyrinth was also changed to accommodate a mechanical seal between the sealing water injection point and the impeller chamber. This seal reduced the leak-in of seal water to the pump to practically zero. Further reduction in sealing water requirements was accomplished by the close clearances in the labyrinth passages so that the overall result was to reduce the injection water, leak-off and leak-in to amounts far below the original predictions and the high pressure leak-off was eliminated completely.

Water-Level Indicators—Four water-level devices were installed on this boiler, consisting of a recorder and an Eye-Hye gage on the operating panel, a double-window Bi-Color gage with 21-in. visibility and mirrors on one end of the drum, and a double-window Micasight gage with 18-in. visibility on the other end of the drum. The indirect type gages have been very satisfactory but they do not give a true indication when the pressure is below the design value, due to change in water density.

Illumination of the double-window Micasight gage was not sufficiently bright to permit the water level to be observed from the operating floor. A single window gage of 12-in. visibility was substituted in August 1943 but after a short period of operation the image of the water level became too faint to be seen from the operating floor. In October 1945 the gage manufacturer installed a new improved illuminator and mirrors to reflect the water level image to a convenient point near the operating floor. Visibility of the image with new mica windows was very clear. It remains to be determined how often the mica will have to be renewed to maintain satisfactory visibility.

The Bi-Color gage has required frequent maintenance. One of the gages was modified by the manufacturer in February 1944. The other gage was modified in a different manner in September 1945.

Burners—The pulverized coal burners are located in the four corners and fire tangentially. No changes have been made except to incline the lowest row slightly downward to improve slag fluidity on the floor.

Research and Tests

Before the boiler was placed in operation over a hundred thermocouples were installed at various points for checking operating metal temperatures on furnace wall tubes, superheater, reheater, economizer, steam drum (lower), feedwater connections to drum and circulating-water connections to pumps. Nearly half of these were installed on the hot face of the furnace-wall tubes about three feet above the furnace floor. Pressure taps and pitot tubes were also installed at various points in the circulating system. During subsequent studies, additional thermocouples were added to the lower drum, circulating pumps, reheater, and on the furnace tubes at different elevations, bringing the total number of thermocouples up to 275.

Steam sampling connections were initially provided on the superheater inlet and dry drum, and for special studies additional sampling connections were made at the dry drum, reheater outlet, high-pressure turbine inlet and outlet. A special calorimeter was installed to check for the presence of steam in the suction pipes to the pumps.

Circulation—One of the first studies was to check total circulation and distribution to the four separate groups of parallel circuits comprising the furnace walls. In each wall one circuit had been chosen for installation of a pressure tap on the downstream side of the orifice. The pressure difference between header and the downstream tap beyond the orifice could then be used to determine the rate of flow through the orifice, using calibration data. All orifices serving circuits of a given wall are the same size and since the pressure drop across the orifices is large compared to that across the parallel heated circuits, very little error is introduced by using the flow through one orifice to calculate the flow for the entire wall. Furthermore, all heated tubes of a given wall are nearly the same length and have approximately the same exposure to heat. By measuring the pressure drop across four furnace-wall orifices, it was therefore possible to determine the total circulation of the unit.

The pitot tubes in the two suction pipes to the circulating pumps provided another means of determining the total circulation except that this would not include the sealing water which leaks into the pump. This leak-in can be checked by determining the difference between rate of feedwater flow and steam flow and making an allowance for blowdown.

Measurement of the pump head provided a third means of checking the pump capacity because a pump characteristic curve had been determined by shop test.

A fourth method was by determining the difference in solids concentration in the water at pump discharge and leaving the evaporating circuits.

Total circulating water flow calculated from the pressure drop across four orifices checks very well with the total flow calculated from pitot-tube measurements in the suction pipes. Distribution of circulating water to the walls can therefore be accurately determined from the same orifice pressure-drop measurements. Distribution is practically the same for any load or pressure.

Distribution of water to the two suction pipes was found to be practically 50–50 when the two outside pumps or the center pump was operating. It was sometimes nearly equal when the center and one of the outside pumps were used but on other occasions the distribution was 45–55.

A study was also made of water distribution to the two legs of bifurcated circuits in the right-hand and left-hand walls.

Other tests were conducted to check the water temperature at several points in the suction pipes between the drum and the pumps, by the use of iron-constantan thermocouples peened into the metal of the pipes under the insulation. The difference between saturation temperature in the drum and the measured temperatures was 6 to 9 F which is about one-half the calculated difference, assuming no condensation of steam to heat the feedwater in the drum.

Furnace-Tube Temperatures—Data obtained at Montaup and already published show that even in a bare-tube furnace and in the zone of highest flame temperature with pulverized-fuel firing the hot-face metal temperature with normal slag covering was only about 50 F above saturation temperature. The tubes are $1^1/_4$-in. OD, 0.165 in. minimum wall thickness but the average wall thickness is probably more nearly 0.180. It may therefore be readily calculated that the heat absorption at the point of temperature measurement was only about 50,000 Btu per hr per sq ft allowing for reasonable drop at the evaporating film. These data also show the effect of deliberately removing the slag and ash coating from a portion of the wall, thus exposing a small surface to the full radiation of the flame at a temperature approaching 3000 F. Under these conditions the skin temperature rose to a maximum value 172 F above saturation (786 F–614 F saturated temp), and the corresponding heat absorption rate would be about 150,000 Btu per hr per sq ft allowing for temperature gradient between inside surface and the evaporating water. These values represent the extreme rate of heat absorption to which these bare-tube walls could be subjected because if a larger area in the zone of high temperature were clean the radiating temperature and the average heat absorption rate would both be lower.

In June and July 1943, a study was also conducted to learn the effect of circulation rate on the polished interior surface of sevreral tube specimens installed in several

furnace-wall circuits. In each of three circuits having different size orifices a pressure tap was available on the downstream side of the orifice so that the water-flow rate in each could be determined by measuring the orifice pressure drop.

There were three thermocouples at the same elevation on each of four side-wall tubes. All these thermocouples were read daily at less than hourly intervals for a month. From these observations it was concluded that variation in circulation from 57 per cent to 230 per cent of normal had no effect on the tube temperatures.

Steam Purity—It was found that the source of make-up water and the season of the year had a marked effect on steam conductivity leaving the high-pressure boiler.

With the boiler operating at 650,000 lb per hr output, and boiler water of 1137 ppm, determination of solids by evaporation was 0.37 ppm.

The conductivity of undegassed steam samples taken from the dry drum ahead of the final drying screens was found to be 4.23 mmho and 4.56 mmho at boiler loads of 620,000 and 650,000 lb per hr, respectively. Other samples evaporated during the same week indicated that the conversion factor was 0.20 or less, so the corresponding total solids in the dry drum would be 0.85 and 0.91 ppm, respectively. This would indicate that without the dry drum the purity would be equal to or better than the minimum required guarantee of 1.0 ppm which has now been established by the American Boiler Manufacturers Association and Affiliated Industires (A.B.M.A. & A.I.).

Effect of Circulation Rate—In June 1944, when it had become apparent that the omission of silica from the water treatment had resulted in improved conditions, special study was commenced involving four circuits in the right side wall. After a year of operation tube sections were removed from these circuits in September 1945. Superficial examination of the tubes indicated that the rate of circulation, within the range of 200 to 75 per cent of normal, had little effect on the appearance of the surface. Regardless of rate of circulation all the tubes had a light coating of black sludge; the side toward the fire was much cleaner than the side toward the casing; metal under the film was very smooth on both fire-side and casing-side except for numerous small pin-point pits which occurred more frequently on the unheated side than on the heated side.

Superheat Control—Automatic regulation of both sets of dampers at economizer outlet results in very close regulation. Starting with the conditions which exist immediately after operating the furnace wall blowers the bypass damper is fully closed or slightly open depending on the rate of output. As the furnace accumulates ash and the gas temperature increases the bypass dampers automatically open and maintain the steam temperature within ±5 F of the desired limit. At the end of an eight-hour operating period the bypass dampers will be 50 to 80 per cent open depending on the output rate and the nature of the coal. Then as the wall blowers are operated the bypass dampers operate automatically to compensate for the effect of removing the ash from the walls and maintain the same close regulation of steam temperature during the cleaning period. Tests were conducted to determine the full effect of operating the bypass dampers from closed to full open.

Capacity and Flexibility—The maximum peak capacity of the boiler has never been determined. The maximum demand has been 670,000 lb per hr but the feeders, burners, fans and circulating pumps are adequate for higher output.

During special tests on the high-pressure turbine wide swings in pressure, output and steam temperature were accomplished very rapidly and with an excellent degree of control.

The boiler has a very stable water level even under extreme operating conditions of sudden load increase or decrease. In fact, sudden emergency load changes have occurred without any perceptible change in water level. Also on the occasion of furnace-tube failures it has not been difficult to maintain water level while reducing load and pressure in an orderly manner.

Efficiency—The contract overall efficiency with coal firing at 650,000 lb per hr output was 89.3 per cent based on coal of 14,200 Btu per lb with 2.8 per cent moisture as fired; and based on 15 per cent CO_2 in gases at economizer outlet, with 290 F gas temperature leaving the air heater, 80 F entering air temperature, and with 0.60 per cent allowance for unburned combustible.

During tests at 650,000 lb per hr output the CO_2 at the economizer outlet averaged 15.2 per cent, the air entering the heaters was 110 F and gas leaving the heaters 306 F. Tests to determine heat loss due to combustible in fly ash were conducted at a later date when the maximum load demand on the boiler averaged 572,000 lb per hr, the CO_2 entering the convection superheater section was 16.0 per cent and the average heat loss in the fly ash combustible for two tests was 0.47 per cent. The results of two other tests with 15.0 per cent CO_2, at the same output, averaged 0.34 per cent heat loss in the fly ash combustible.

Special Studies of the Feedwater-Steam System

By W. D. BISSEL,* B. J. CROSS† and H. E. WHITE‡

During the course of a complete investigation of the high-pressure forced-circulation boiler at the Somerset Station covering the past three years, a special study was made of the feedwater and steam system, particularly with reference to the dissolution of iron throughout the system and the formation of high iron sludges within the boiler. Deposits were found throughout the boiler, as a slime on surfaces not exposed to heat and in a baked-on, semi-scale-like form on active steam-generating surfaces. They were not, however, true scales and could easily be removed with a stiff brush.

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‡ Stone & Webster Engineering Corporation.

Composition of the sludge varied with location in the boiler, but all deposits had a high percentage of iron as magnetic oxide, phosphate sludges as a secondary constituent, and varying amounts of copper.

Water supplied to the boiler is condensate plus makeup from evaporators. A simplified diagram of the feedwater system is given in Fig. 1, sampling points along the path of flow being marked by letters *A* to *M*. Chemicals are introduced after the deaerator.

Scope of Program

Following a thorough cleaning of the unit by acid wash late in December 1943, a close watch was maintained on the water fed to the unit, the steam produced and the blowdown removed. This study was

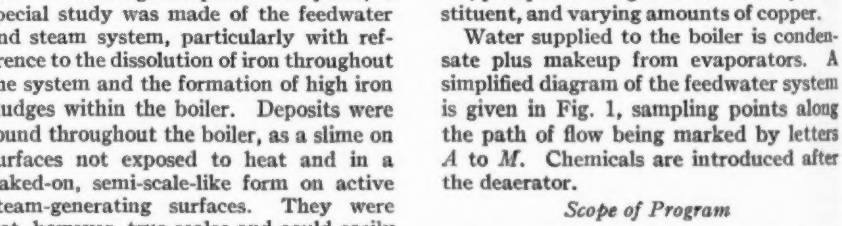

Fig. 1—Diagram of feedwater system at time of tests

later extended to cover the feedwater system from the hotwell to the boiler. For convenience in presentation, the work is reported in the following three phases:

Period 1—(*a*) hydrogen in feedwater and steam; (*b*) total solids in feedwater, steam and blowdown; (*c*) measurements of suspended solids; (*d*) study of gases in steam.
Period 2—Exploration of the feedwater system for dissolved hydrogen, iron, and for pH.
Period 3—(*a*) measurement of copper in condensate; (*b*) bead- and ion-exchange column tests; (*c*) measurement of tube temperatures; and (*d*) corrosion detector.

Dissolved-hydrogen recorders were set up to sample the feedwater entering the economizer or boiler and the steam leaving the boiler. Also, a dissolved-oxygen recorder was installed to sample water fed to the unit. For the three-month period, covering January, February and March, these measurements showed hydrogen high at the start, but later decreasing; that much of the hydrogen in the steam entered the boiler with the feed; and some traces of oxygen that were later corrected.

The first approach to the sludge problem was a study of the total solids entering the boiler with the feed and the amount leaving with the steam and with the blowdown. Samples of three liters each were taken for feedwater and steam, and $^1/_2$ liter for blowdown. Total solids were determined by evaporation and weighing. Iron was determined in the residues of a number of these samples. Steam and water flows were read from the station meters and the entire blowdown was passed through a cooling coil and weighed. These tests showed a positive unaccounted-for quantity of both total solids and iron that presumably remained in the boiler.

It had long been noticed that at shutdowns of the unit the boiler water became turbid with the maximum turbidity occurring at 600 to 400 psi, at which point the fires were generally extinguished. Advantage of this is taken to blow down much of the accumulated sludge, and it at least affords a relative measure of the amount of sludge in the boiler. During the three months the boiler was shut down or reduced in pressure and load at weekly intervals and the turbidity measured. A graphical record of a typical shutdown is shown in Fig. 2. The boiler-water turbidity as measured in these tests decreased with time reflecting the reduction of contamination in the feedwater system and the improvement in sludge blowdown.

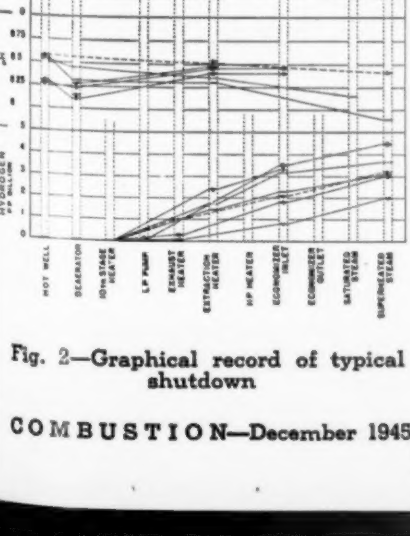

Fig. 2—Graphical record of typical shutdown

Investigations of the second period consisted of exploration of the system for dissolved hydrogen and iron and for pH. In addition to the two hydrogen recorders permanently located at the feed to the economizer and at the superheated steam line, a third was set up at the hotwell and a fourth arranged so that it could be moved to various locations along the line of water flow. Measurements of pH were made at various sampling points and samples were taken for determination of iron. The results are given in Fig. 3. It will be noted that this covers different load and pressure conditions, and each set of points represents averages of daily samples over 6- to 8-day periods. There was no hydrogen detected at the hotwell, the deaerator or the 10th-stage heater, and apparently no correlation with load or pressure. The pH value of the samples varied over a narrow range, that at the hotwell ranging from 8.3 to 8.6. There was a reduction in the deaerator due to removal of gases, and a rise at the extraction heater, ascribed to the chemicals introduced ahead of that point.

All of the hydrogen entering the boiler with the feedwater originated in the feedwater system. No hydrogen is recirculated through the hotwell. There was a consistent agreement between the iron pickup and the amount of hydrogen evolved.

Miscellaneous projects were grouped in the third period.

As the condenser was suspected of being the principal source of copper contamination, the investigation of copper was limited to this equipment. Samples of the 15th-stage heater drips were taken as representative of the steam ahead of the condenser and compared with samples of condensate from the hotwell. Samples were also taken of water at the deaerator outlet and of saturated steam. The results showed a small but consistent increase in copper across the condenser, and some copper was detected in the steam. Other possible sources of copper, which were not investigated, were the 10th-stage heater and the low-pressure pumps which have bronze impellers.

The plating-out effect of iron-rich deposits on conductivity coils, glass tubing and rubber tubing through which samples of feedwater and steam are drawn has long been noted in other plants and was also observed at Somerset. Therefore, bead- and ion-exchange column tests were conducted, periodic samples being taken of the influent and effluent and tested by conductivity for iron and pH. The extracts of the accumulated material were analyzed for iron and copper.

The mechanism of plating-out effect,

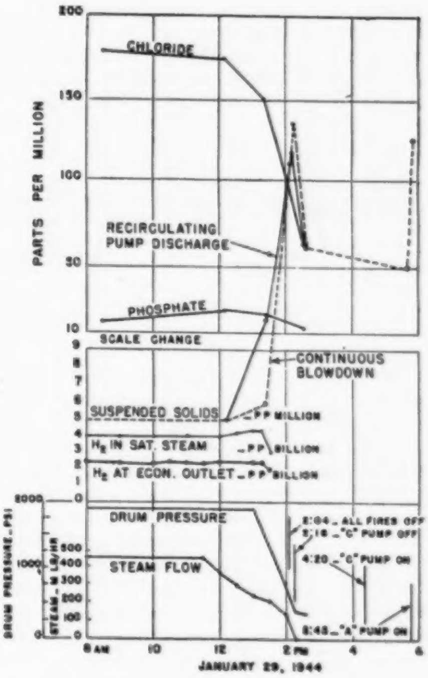

Fig. 3—Hydrogen, iron and pH values at various locations

while not definitely known, appears to be one of surface adsorption. Analysis of the deposits showed ferric iron, hydrated ferric oxide, magnetite and silica. It is probable that the same effect continues throughout the piping of the feedwater system and in the boiler.

Tube-temperature measurements are reported in another paper of this group. One purpose of these measurements was to determine whether there was any progressive increase in temperature that could be ascribed to internal deposits; but no such increase was noted.

In an attempt to obtain a measure of the rate of attack on the internal surfaces of feed piping, a low-carbon steel detector was located inside a branch of the feed line near the boiler. After a year's exposure it was found to have lost 0.25 gram of its original weight of 14 grams. This represented a surface loss, if evenly distributed, of 0.0003 in.

Conclusions

The rate of metal loss from the feedwater system appears to be small and would not ordinarily lead to any great concern if evenly distributed over the surface exposed, but the concentration of attack on small local areas is always to be feared. The mechanism of attack of this type of corrosion is not well understood, nor have preventative measures been well established.

The principal concern over the presence of iron and copper in boiler feedwater is caused by the propensity of these substances to form adherent sludges on the boiler surfaces. The chief danger lies in their insulating effect on active steam-generating surfaces where it may build up to a thickness that may result in overheating the tube.

Basically the problem results from the

introduction into the boiler of more solids, or substances that form solids, than are removed. The two obvious lines of approaching the problem are (1) to prevent or reduce the production of metallic ions in the feedwater, and (2) to provide for their continuous removal from the boiler. Until this problem is completely solved, periodic cleaning of high-pressure boilers will still be necessary.

Water Conditioning for 2000 Psi Pressure

By W. W. CERNA* and R. K. SCOTT*

CONSIDERABLE interest has been aroused in the chemical treatment used for the high-pressure boiler at the Somerset Station. The theoretical aspects of the present treatment, which has been in use since January 1, 1944, were given in a paper by Hall[1] presented at the annual meeting of the A.S.M.E. in December 1943. Details of the results obtained with the different types of treatment used on this boiler were given in a paper by Parks[2] at last year's annual meeting. It is largely the purpose of the present paper to present the reasons for the various methods of chemical treatment which have been used, and for the changes made, which have resulted in stabilization of the boiler-water conditioning since January 1, 1944.

Period of Sodium Treatment

When the boiler first went into preliminary operation in June 1942 a fairly standard treatment, using sodium chemicals, was used, with the following control limits.

Alkalinity as sodium hydroxide, NaOH	50–60 ppm
Sodium phosphate, Na_3PO_4	50–70 ppm
Total solids	1000 ppm max.

Some months later it was also decided to feed and maintain a positive reserve of sodium sulphite in the boiler water. During the period this treatment was used, several tube failures occurred. Internal boiler conditions were also found unsatisfactory. Evidence of the "hide-out" of sodium sulphate and sodium phosphate was found which indicated that some of the boiler water was being concentrated much beyond the limits of the normal overall boiler water. For example, using the published data of Schroeder, Berk and Gabriel[3] for the solubility equilibria of sodium sulphate and sodium phosphate at boiler temperatures, a boiler water at 595 F containing 350 ppm of sodium sulphate (Na_2SO_4) and 70 ppm of trisodium phosphate (Na_3PO_4) representative of that in the Montaup boiler at the time, would have to concentrate about 185 times before the first deposition of these substances would commence. Neglecting the effect of the sodium hydroxide on the solubility equilibria, which would actually be in the direction of increasing the number of concentrations, no deposition of sodium sulphate or sodium phosphate from the boiler water would be possible until the concentration of sodium hydroxide had likewise increased 185 times. If the initial concentration were 60 ppm of sodium hydroxide, the water just about to lay down solid sodium sulphate and sodium phosphate at the evaporative surface would necessarily contain 11,000 ppm of sodium hydroxide or a 1.1 per cent solution of NaOH. Thus, it is apparent that in establishing the water conditioning for such high-pressure boilers, it is necessary to think in terms of the concentrated films, and not merely of the overall boiler water analysis, such as represented by the analysis of a representative sample taken from the boiler.

By the time the need for improving boiler-water conditions at Montaup became apparent, considerable of the work developed in the paper by Hall had already been made available. Therefore, the boiler was cleaned of existing deposits by means of inhibited acid and a different treatment instituted.

Preliminary Potassium Treating Period

The studies indicated that while sodium silicate would "hide-out" and be scale-forming the same was not true for potassium silicate as long as the silica to alkali ratio, in equivalents, was maintained at 1.6 or less, so that the highly soluble potassium metasilicate or disilicate would exist, even though considerable concentration due to film boiling might occur. This made the maintenance of some silica in the boiler water, if it could be kept in the soluble form, desirable as a means of decreasing the amount of sodium hydroxide concentration which could develop in a concentrating film. Furthermore, considerable magnesium phosphate had been found in various boiler deposits during the period of sodium treatment, and the maintenance of some silica in the boiler water would be advantageous for precipitating the magnesium as magnesium silicate, which has been proved to be the most desirable form of magnesium sludge in boiler water, with minimum tendency for the formation of adherent deposits. To obtain the advantage of these developments, the boiler-water conditioning control started after the acid cleaning in April 1943 was established as follows:

pH value	10.2–10.7
Phosphate (PO_4)	30–50 ppm
Sulphite (SO_3)	2–5 ppm
Silica (SiO_2)	7–10 ppm
K to Na ratio, equivalents	2:1 Min.
SiO_2 to alkalinity ratio, equivalents	1.2:1 Max.

Inasmuch as the plant uses tide water for cooling purposes, so that even small amounts of condenser leakage introduced considerable sodium in the boiler water, it was necessary to feed potassium chloride, in addition to the potassium phosphate, sulphite and silicate, to maintain the desired potassium to sodium ratio.

A number of tests which were conducted after the boiler was returned to service with the use of potassium chemicals showed quite promising results. One of the most interesting features was the virtual elimination of sulphate and phosphate "hide-out." The lack of "hide-out" with potassium treated boiler water contrasted sharply with the large amount of "hide-out" indicated by the sodium sulphate and sodium phosphate, obtained during the period of sodium treatment.

Several boiler inspections after relatively short runs, following the use of potassium chemicals, also showed promising results inasmuch as the boiler internals prove to be quite clean. Therefore, the boiler was operated at full design pressure and the maximum load desired by the plant, generally between 550,000 and 600,000 lbs of steam per hour.

A number of special tests were also made during this period which produced a number of interesting results. For example, it was found that in this boiler high silica concentrations were unstable, and it was therefore inadvisable to try maintaining more than 10 ppm of silica in solution in the boiler water.

The work of Hitchens and Purrsell[4] indicated that very little decomposition or auto-oxidation of sodium sulphite occurred up to a steam pressure of 1775 psi. However, in the Montaup boiler, considerable decomposition of sodium sulphite had been indicated whenever efforts were made to maintain more than a few parts per million in the boiler water. In this respect, the potassium sulphite proved similar, and therefore the decision was made to maintain only a few parts per million of sulphite in the boiler water, to serve primarily as an indicator of whether or not dissolved oxygen was entering the boiler with the feed water.

In December 1943 a roof tube failed, apparently due to sludge accumulation in the rear wall header around the strainer supplying the orifice which fed this particular tube. A number of tube sections were cut out at this time and considerable iron oxide formation was found on the tubes, particularly on the fire side. Pickling some of the tube sections also disclosed a thin yellow ribbon of acmite, sodium-iron-silicate scale, on the fire side of a number of the tubes. It is perhaps noteworthy that during the period of potassium and silicate treatment the boiler had been operating at full design pressure and had generated considerably more steam with but one tube failure than it

* Hall Laboratories, Pittsburgh, Pa.

[1] "A New Approach to the Problem of Conditioning Water for Steam Generation," by R. E. Hall, *Transactions A.S.M.E.*, vol. 66, 1944, pp. 457–488.

[2] "Experience with Sodium and Potassium Chemicals for Boiler Water Conditioning at Montaup Electric," *ibid.*, vol. 67, 1945, pp. 335–338.

[3] "Solubility Equilibria of Sodium Sulphate at Temperatures from 150–350 C. III, Effect of Sodium Hydroxide and Sodium Phosphate" by W. C. Schroeder, A. A. Berk and Alton Gabriel, *J. Am. Chem. Soc.*, vol. 59, 1937, pp. 1783–1790.

[4] "The Behavior of Sodium Sulphite in High-Pressure Steam Boilers," by R. M. Hitchens and J. W. Purrsell, Jr., *Transactions A.S.M.E.*, August 1938.

had during the period of sodium treatment during which three tube failures had occurred.

The boiler was again acid-washed, using inhibited hydrochloric acid with some bifluoride added in order to remove the silicate scale as well as the iron oxide formation. In order to eliminate further sludge accumulations at the ends of the rear header, arrangements were also made to interconnect each end of the rear-wall header with the adjacent side-wall header.

Potassium Treatment in Use Since January 1, 1944

In putting the boiler back on the line, it was decided to discontinue the feed of silica, because of the slight but definite acmite formation which had been produced on the fire sides of a number of the tubes. It was also deemed advisable to continue with potassium boiler-water treatment because of the lack of "hide-out" when potassium chemicals were used in the boiler-water conditioning. Furthermore, a number of other plants which had substituted potassium chemicals in place of sodium chemicals for high-pressure boiler-water conditioning, had also found considerably less phosphate sludge in the boilers following this change, even though silica feed had not been used. This factor was also an influence in the decision to continue with potassium treatment.

The detailed control limits which were established and have been maintained since January 1, 1944, are as follows:

pH value	9.8–10.4
Phenolphthalein alkalinity (ml, $N/30$ acid required for 100 ml. sample)	0.5–1.6
Phosphate (PO_4), ppm	8–20
Chloride: hydroxide ratio, epm	Minimum = 10:1
Potassium: Sodium ratio, epm	Minimum = 3:1
Total solids, ppm	Maximum = 1000

Actually, the control has worked out so that the chloride to hydroxide ratio, in equivalents, is seldom below 50:1.

High-Pressure Boiler Feedwater

The nature of the boiler feedwater is also a factor which cannot be ignored, especially in the operation of high-pressure boilers.

The boiler feed-water at Montaup is obtained from the turbine condensers plus a small amount of evaporated makeup water. Control to maintain good feed-water conditions is normally maintained at the plant, as proved by some 15 years' operation of the 400-psi boilers without difficulty in the preboiler equipment. However, with the advent of the early difficulties encountered in the operation of the high-pressure boiler, steps were taken to further improve the quality of the feedwater wherever possible. Operation of the two deaerators was adjusted so that they would always be under positive pressure to assure good elimination of dissolved oxygen. The turbine condensers were also retubed in 1944 to assure minimum contamination by the tide-water used for condenser cooling.

These steps have resulted in feedwater which generally shows zero values for dissolved oxygen. Carbon dioxide in the system is also very low, due to the feed-water to the evaporators being a sulphate rather than a carbonate water. Tests made on the steam indicate that the carbon dioxide content is of the order of 0.01 ppm. Measurement by means of an L. & N. pH meter on flowing cooled samples, right at the sampling points after the deaerators, generally shows pH values of about 8.5.

Condenser leakage is immediately indicated on the condensate conductivity recorders, and if this becomes at all high, the condenser is taken out of service as soon as possible and the leaking tubes located and plugged. As a result of this control, the turbine condensate used for feedwater has averaged less than 5 micromhos/cm conductivity, since the summer of 1944.

Examination of Boiler Tube Sections

The removal of tube sections for examination rather than merely examination and analysis of such deposits as are found in the wet steam drum, has greatly facilitated the determination of internal conditions of the Montaup boiler. We have thus been able to study the distribution of constituents of the deposit between the fire and cold sides of the tubes, as well as between the surface of the deposit and the area next to the metal.

Conclusions

Operation of the Montaup high-pressure boiler since April 1943 when potassium treatment was first instituted has been decidedly successful, with operation at full design pressure and generally near design load as required by the plant.

There have been only two forced boiler outages since April 1943 associated with internal boiler deposit. This number of failures in $2^1/_2$ years' operation can be equalled or bettered by very few boilers operating at 1950 psi or higher.

In arriving at the boiler-water control for high-pressure boilers, not only the overall boiler-water conditions must be considered, but attention must also be focused on the type of water which will develop when abnormally high concentrations occur, such as follow with but a few degrees film-temperature increase above the overall boiler-water and saturated-steam temperatures.

It is felt that the advantages of potassium equilibrium in the boiler water have been definite contributing factors to the operating record of this boiler, similarly to a number of other boilers operating at pressures of 600 psi or above, where definite improvements in internal boiler conditions or maintenance of turbine capacities, or both, have resulted.

Instruments and Control Equipment

By W. D. BISSELL* and E. B. POWELL†

INSTRUMENTS and automatic regulating devices which serve for operation control on the 2000-psi boiler at Somerset Station are conveniently considered in three groups. In the first group is classed equipment serving primarily for stabilization of output and efficiency of combustion; in the second group, equipment for maintenance of water conditions; a third grouping is employed for permanent instruments and controls installed to meet the special needs of forced circulation.

The functions served by the instruments and control equipment of Group 1 are essentially those to be met in the operation of any modern boiler of equal capacity. They include pressure gages for steam, water and air; flowmeters for steam, water and fuel oil; feeder speed indicators and recorders for pulverized coal delivery; instruments for evaluation of combustion efficiency; boiler-drum water-level recorder and drum water-level indicators; combustion and steam-pressure control; steam-temperature control; feedwater pressure and flow-control devices. The main control panel mounts instruments and controls primarily of this group.

Mounted on a separate panel on the opposite side of the aisle facing the main control board are a group of instruments serving primarily to place control of 375-psi superheated steam temperature in the hands of the high-pressure boiler operator. Control valves for the desuperheating station ahead of the reheater, while not operated from the panel, are readily accessible at the rear of the boiler. Controls for the 10-in. pressure-reducing and desuperheating station and for pressure reduction ahead of the 4-in. desuperheater are on the main board.

Variations in superheated steam temperature on the low-pressure system are caused usually by variations in loading of low-pressure boilers, which take up all load swings within the limits of their operating capacity. The throttle steam temperature on the low-pressure turbines must be held within close limits. Obviously, maintenance of mere constancy of reheated steam temperature would not meet the requirements. Accordingly, manual adjustments are made in desuperheating the low-pressure steam prior to reheating, or in automatically controlled temperature of pressure-reduced steam, or in both. The indicating pyrometers on reheated steam and on steam at the throttles of the two low-pressure turbines give the operator clearly readable and closely concurrent values at these points at all times.

Adjacent to the low-pressure system steam-temperature control panel, is a 12-point potentiometer indicator for checking recorders and for reading instantaneous temperatures. With multipoint re-

* Montaup Electric Company.
† Stone & Webster Engineering Corporation.

corders several minutes may elapse between temperature measurements for a particular point. The indicators bridge the gap and give values instantly or continuously as desired.

The boiler feed pump instrument panel is on the main operating floor. On it are mounted a recorder for steam flow to turbine-driven feed pumps and for high-pressure boiler feedwater flow and pressure and a recording pyrometer for feedwater temperature at several stages of heating, as well as indicating gages for individual pump suction and discharge pressures, pump turbine-drive exhaust and extraction pressures, and pressure differential between the boiler drum and main feedwater header. Additional feedwater system pressures and temperatures are indicated on the gages of the feedwater heater instrument panel. On this panel are also mounted controls for motor-operated feed-line valves at the high-pressure heaters and alarms for water levels in the shells of closed-type heaters. This panel is located on the ground floor.

Combustion Control

Combustion control is, of course, initiated by change in steam pressure, with auxiliary adjustments from the accompanying steam flow and gas flow. The measurements of steam pressure and steam flow are usually direct and accomplished with adequate precision without regard to boiler design. On the other hand, for the modern boiler with heating surface almost exclusively of the radiant type, especially where the superheater is under gas bypass control as in this boiler, inherent sources of draft loss appropriate for the measurement of combustion gas flow or combustion air flow are not so obvious. Control equipment and certain instruments used for giving a running check on control efficiency are dependent upon the precision of this measurement.

Before going into the experiences in measurement of combustion gas flow on this boiler it should be pointed out that superheated steam temperature is controlled by diverting through the upper economizer a part of the combustion gas flow which would otherwise make full travel of the convection bank of the superheater. Steam temperature is held very closely, swings in temperature rarely exceeding 5 deg F even during operation of soot blowers.

For recording steam flow-air flow relations, the combustion gas flow initially was to be based on the differential across the steam reheater. It early became evident, however, that the normal gas resistance of the reheater was not great enough to give consistent measurement of gas flow and connections were made to provide for summation of straight-line functions of economizer draft drops, paralleling the corresponding arrangements for combustion control. For metering purposes an effort was made to compensate for variations in gas density by making the two pressure connections on the flue at the same level and extending the trailing pressure lead to the outlet of the economizer within the gas stream. Attempts toward close coordination in combustion control encountered the fact that pressures measured at the downstream connections in the economizer casings were seriously influenced by flow disturbances varying with the positions of main and by-pass dampers. In addition, apparently the economizer gas pressure differentials were affected by accumulating deposits on economizer surfaces and by flow disturbances from slag and ash accumulations in the superheater and reheater ahead of the economizer. These factors gave an annoying lack of consistency in gas pressure differential in relation to actual rate of gas flow.

After exhaustive efforts to improve performance, it was decided to abandon use of the steam-generating equipment proper as a source of gas pressure differential and install restricting baffles to form an orifice in the short length of flue between the economizer outlet dampers and the air heater. Observations with this arrangement, however, demonstrated that the pressure loss as measured across the restricting baffles was also influenced by the position of the dampers.

Air heaters of the rotating type are generally regarded as too unstable in draft characteristics for evaluating rates of gas flow, their variations in leakage and in resistance of path being thought too great to permit use of a device of that kind in the control of combustion and the metering of gas flow. However, use of the air heater pressure differentials was adopted as a last resort, and results have been very promising.

Protective devices associated with the combustion control are arranged to give instant stoppage of fuel, coal or oil, on loss of primary air, on excessive back pressure in the furnace, or on failure of both induced-draft fans and, under this last condition, forced-draft and primary-air fans will be tripped out. The use of controlled circulation requires also that all fuel be instantly cut off on failure of circulation, which in this case is effected by the pressure differential across the circulating pumps on dropping to 20 psi.

It still cannot be too strongly stressed that successful operation of automatic controls is inescapably dependent on their conscientious routine inspection and maintenance and, where compressed air is the control impulse fluid as in this case, absolute cleanliness and dryness of air and reliability of air supply are vital.

The control and instrument equipment of Group 3, having to do primarily with control of the boiler circulation, are of the general type of Group 1. There are three pumps, one motor-driven and two with combined motor and turbine drives. The gages of the two upper rows on the panel are arranged in three groups, showing, for each pump labyrinth seal injection and leak-off pressures and pump-drive-motor amperes. Rise in labyrinth leak-off pressure, indicating an increase in sealing water requirements, has served to give warning of wear in the labyrinth gland. The three gages of the next row below are for pump suction and discharge header pressures and steam pressure available at the pump drive turbine throttles.

In addition to the control facilities at present in use, three differential pressure recorders have been provided and are now mounted in place, but not yet connected, on a separate panel near the main operating board. These recorders will give, for each of the three pumps, continuous record of pressure differentials between suction and discharge and between discharge and labyrinth gland seal injection.

Daily Test Routine Inadequate

Preliminary operation of the high-pressure unit early demonstrated that the simple daily test routine which had served for the older 375 psi plant was far from meeting the needs of close control of water conditions for the high-pressure boiler. More observations and more frequent observations were necessary to avoid too long continuance of contamination or too wide discrepancy between coincident chemical requirements and actual chemical concentrations. Specific factors determined as commonly contributing to upsets of water conditions and found calling for more prompt detection have included condenser leakage, evaporator carryover, chemical feed variations, change in continuous blowdown recirculation, change in continuous blowdown to waste, contamination of stored condensate, subatmospheric pressure in deaerators, and carryover by steam from low pressure boilers.

Hazards associated with condenser leakage in a seaboard plant hardly need comment. Evaporator carryover at Somerset Station presented a greater than usual problem because the makeup feed is drawn from a surface supply subject to seasonal organic contamination. The severe foaming which, prior to the installation of supplemental washing scrubbers on the evaporator vapor lines, was liable to occur at unexpectedly low evaporator concentration, was also very liable to pass undetected by any usual spot sampling routine.

Hydrogen evolution at the steel surface was believed to give a reliable index of the rate of metal loss in absence of free oxygen in the system. Consequently, among the first of the new instruments selected was a two-point hydrogen, single-point oxygen recorder. Also, for promptness in detection and identification of departures from scheduled conditions, recorders were provided to cover continuously the test values of high-pressure feedwater and boiler water pH and conductivity, and high-pressure steam and evaporator vapor conductivity.

The high-pressure turbine operator makes hourly log entries of chemical pump operation and continuous blowdown valve settings; also, of recorded high-pressure feedwater oxygen and hydrogen concentrations; conductivity; and pH; boiler-water conductivity; and superheated steam hydrogen concentration and conductivity. Because of the importance of stability of water conditions, the operator makes hourly tests of the high-pressure continuous blowdown water for alkalinity, phosphate concentration, and pH value as running checks on the recorders. With the close observation of water conditions so maintained in such comprehensive scope even a slight change is quickly detected and usually its source rather promptly identified so that, in general,

correction can be made before any serious effects have resulted.

The more complete daily analysis of high-pressure boiler water and boiler feedwater is made by the plant laboratory and these results are used as the overall check on the hourly tests for basic control of water conditioning. The extremely low values to which contamination from hardness-producing salts is held in the condensate of this tidewater station make it practicable to recirculate boiler blowdown water to assist in stabilizing feedwater alkalinity and deliver the normal dosage of all water conditioning chemicals continuously at the outlet of the deaerators to be carried through all higher-temperature heat-exchange equipment to the boiler. A high-pressure chemical pump is available for delivery of chemicals directly to the boiler drum as special conditions may require.

Notwithstanding the generally small values of feedwater contamination, the recording instruments give very practical demonstration of the importance of continuity and uniformity in chemical feed.

After considerable preliminary investigation of sources of hydrogen liberation in the high-pressure system, permanent connections for sampling were established.

Under current normal operating conditions the oxygen concentration recorded is "zero," expressed in parts per million, and the approximately full-load concentrations of hydrogen are close to 2 parts per billion in the feedwater at the economizer entrance and below 3 parts per billion in the superheated steam as delivered to the high-pressure turbine. Other full-load characteristics recorded by the instruments of Group 2 are conductivity of steam about 1.5 micromhos as sampled, varying with the seasons, and 0.6–0.7 micromho degassed; conductivity of chemically treated feedwater about 5 micromhos; conductivity of boiler water about 1000 micromhos; pH value of feedwater 8.3, and pH value of boiler water 10.3.

It had, of course, been recognized that hydrogen evolved in the feedwater system or boiler might combine to some extent with oxygen where found dissolved in the water in contact with the metal surface. A contingency overlooked was that an oxide of copper might function in the system as a source of oxygen. The practical importance of chemical action of that sort was brought strongly to attention by the October 26, 1945 furnace tube failures taking place without marked increase in recorded rate of hydrogen evolution in the boiler. One of the low-pressure turbine stage heaters, temporarily operated as an evaporator condenser with feedwater entering at 215–218 F and condensing vapor of about 16 psi gage pressure, corresponding to about 250 F, had been returned to this vapor condensing service October 10 in the midst of the season of maximum organic contamination of the evaporator water supply and immediately following installation of 468 new tubes of Admiralty alloy. Apparently, the copper carried into the feedwater system in oxidized form from the corrosion of the new Admiralty alloy tubes was sufficient to cause practically complete disposal of the hydrogen evolved from the overheating of the boiler tubes. Although the boiler had been in operation less than a month following an inspection when the drum had been cleaned, considerably in excess of the quantity of metallic sludge expectable from six months of operation was found to have accumulated in this brief period; and the sludge was approximately two-thirds copper, fully one and one-half times the proportion of that metal previously found.

A factor which will be recognized as commonly responsible for hydrogen concentrations out of step with temperature or other corrosive influences normally to be associated with concurrent operation is the abnormally high chemical activity of the metal surface following an acid cleaning of the boiler.

Conclusions

It will be obvious from the experience in operation of this boiler that on modern steam-generating equipment instruments appropriate to the requirements, especially recording instruments, can be not merely informative but of tremendous instructive value and sources of heightened interest in operating personnel. The importance and the potentialities of such instruments doubtless increase with the degree of operating efficiency which it is desired to maintain and, for a base-load unit of the capacity and type of this boiler, become essential. To fulfill their potentialities—in fact, to avoid real hazard from their presence—the instruments must be rugged by the station environment standard rather than by that of the laboratory and must be followed with definitely scheduled routine inspection, calibration and maintenance of frequency and thoroughness that will assure precision of indication within acceptable limits at all times.

Consolidated Edison Company Announces Expansion Program

Ralph H. Tapscott, president of Consolidated Edison Company of New York, has announced that $22,500,000 has been authorized to continue modernization of its Waterside electric generating station, which program was begun in 1935. This is an important feature of a post-war expansion program laid out by Consolidated Edison Company, calling for expenditures of approximately $120,000,000 in the next five years. The program will add about 350,000 kw to generating capacity, increasing it overall about 15 per cent; it will enlarge gas and steam production facilities and will reinforce and extend distribution systems for electric, gas and steam services, particularly electric lines in districts of anticipated rapid growth.

The $22,500,000 expenditure authorized for the Waterside Station covers the purchase of a 50,000-kw, 1600-psi, 950-F topping turbine-generator, two 60,000-kw low-pressure turbine-generators and a high-pressure boiler with a capacity of a million pounds of steam an hour. This high-pressure turbine-generator will be the fifth such unit to be installed in Waterside Station since modernization was begun.

In order to make space for these new units, installation of which will require approximately three years, old and less efficient equipment will be taken out of the station, including three turbines of 20,000-kw capacity each and 35 small boilers of 30,000 lb per hr each. With these units removed, the net increase in generating capacity at Waterside because of the new units will be 110,000 kw, or 25 per cent of present capacity. Other improvements at this station include erection of new electrical galleries and the installation of four major bus sections to take care of expected growth in electric load in the midtown section; also the construction of two new 30,000-kw tie feeders between Waterside and the Hell Gate Station, and rearrangement of existing feeder lines to provide two direct ties between the Waterside and Hudson Avenue Station in Brooklyn.

The long-distance program contemplates the installation of a sixth topping turbine-generator at Waterside, probably by 1950. The entire modernization of this station thus completed will then have cost approximately $65,000,000, making it one of the world's most modern and efficient electric generating stations.

The first part of the program to be completed will be a topping turbine-generator installation at Hell Gate Station, where a 65,000-kw unit begun in 1944 is expected to be ready for service in the spring of 1946. This will operate at 900 psi, 950 F with steam supplied by two 900,000-lb per hour high-pressure boilers. The new unit will yield combined generating capacity of 200,000 kw, since exhaust steam from it will be used to generate electricity in existing generators using lower steam pressures.

Other notable items in the five-year program include a topping turbine-generator of 50,000 kw capacity at the Sherman Creek Station, to be ready for operation in the summer of 1947. This unit will operate with steam at 1600 psi, 950 F, supplied by a boiler of a million pounds per hour capacity. At the East River Station a small turbine-generator of 7500-kw capacity will be installed to exhaust to the mains of the New York Steam Corporation.

To Take Over Ordnance Plant

Secretary Ickes has announced that the Bureau of Mines will take over the Missouri Ordnance Works, near Louisiana, Mo., a plant that made synthetic ammonia during the war, and will convert it into a demonstration plant for the production of gasoline and oil from coal and lignite. Acquisition of this $17,500,000 plant will save several million dollars in construction costs and will speed up the Bureau's synthetic liquid fuels research program. Usable facilities at the Ordnance works will be buildings, the power plant, water supply system, fuel-handling system shops, etc., although additional structures and equipment designed specifically for synthetic fuel production will be necessary.

Personals

Charles W. E. Clarke has been elected vice president and combustion engineer of United Engineers & Constructors, Inc., Philadelphia. He has long been identified with that organization as mechanical engineer and is widely known in the field of power plant design.

Carl A. Marshall has joined the Fairmont Coal Bureau, New York, as fuel engineer to assist in its expanded program. He recently returned from 16 mo. duty in the European theater, as a major in the Corps of Engineers, U.S.A., where he served as chief of the Petroleum and Fuel Branch. He was previously a mechanical engineer with Consolidation Coal Company.

Dr. C. J. Potter has resigned as Deputy Solid Fuels Administrator for War and has been succeeded in that position by **Dan H. Wheeler.** After four years in Government service, Dr. Potter is returning to Indiana, Pa., to devote his full time to the position of assistant to the president of the Rochester and Pittsburgh Coal Company.

Hugh D. Nickle who for the past eight years has been associated with Combustion Engineering Corporation, Ltd., Montreal, as a mechanical engineer specializing in equipment for the pulp and paper industry in Canada has been transferred to the New York Office of Combustion Engineering Company, Inc. He will devote his time to sales work and other contacts in connection with the installation of C-E Chemical Recovery Units in pulp and paper mills in the United States. In this work he will be associated with A. L. Hamm who has long been identified with the design and installation of such units and is widely known as an authority in this field.

Hugh D. Nickle

CATALOGS & BULLETINS

"Horizons"

Byron Jackson Company has just published "Horizons"—an outstanding 72-page book which covers the development and activities of the Company from its inception in 1872 until today. It is the story of American inventiveness and enterprise, and the record of this company's achievements in many fields of industry that has made the name Byron Jackson synonymous with centrifugal pumps. Pictures and text portray the industrial horizon of yesteryears, and, with this background of accomplishment in the past, the BJ organization confidently faces the new horizons of today and tomorrow.

Open Channel Meters

Bailey Meter Company has published Bulletin No. 62 featuring Bailey Open Channel Meters for sewage industrial wastes, sludge and irrigation water. Meters described are of both the direct mechanical and the electronic telemeter type, and wide selection of registers having various combinations of indicating, recording and integrating features is illustrated. All types of registers are said to be suitable for use with flumes, weirs and atmospheric discharge nozzles.

Pneumatic Transmitters

Republic Flow Meters Company has published a 28-page Data Book (No. 1000) which lucidly describes and illustrates the operating principle of its various types of pneumatic transmission equipment for converting process variables such as flow, liquid level, pressure or liquid density into air pressures which vary proportionately with the process variables. A gage or receiver connected anywhere in this transmission line can be graduated to permit direct reading of the measured variable. This pressure can also be used as the measuring impulse for the actuation of an automatic controller.

Refractories and Insulation

Refractory & Insulation Corporation has issued under one cover several bulletins which describe many of its products. These include R & I Stic-Tite plastic insulation; insulating block; blanket insulation, duct linings, refractory cements, etc. Products are pictured in numerous halftones, prices are given and descriptive data include hot and cold face temperatures for various thicknesses.

Tube Protectors

Crane Packing Company has issued a 4-page illustrated bulletin describing its James Crane condenser tube protector. This protector is made of a special plastic material which is claimed to be highly resistant to abrasion.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Applied Energy Conversion

By B. G. A. Skrotzki and W. A. Vopat

In view of the broad title it may be well to point out here that the text deals with power plants of the steam, internal-combustion, and hydro types with considerable attention being paid to the general economic side of power production and performance. Typical equipment entering into such plants is briefly described and illustrated, without going into design problems, as it is felt that these come within the province of specialists among the equipment manufacturers. Moreover, such problems are seldom static.

Beginning with a chapter on "Raw Energy," devoted to the classification and characteristics of coals, oil, gas and refuse fuels, the book takes up, in order, combustion calculations, methods of firing, steam-generating units, prime movers, feedwater systems, steam plant cycles and heat balance, diesel and gas engine plants, hydro power, power plant developments, general economic problems, load curves, selection of plant and equipment, and station performance and operating characteristics; also concluding chapters on specific energy problems and energy rates.

The text is apparently written for students in heat-power engineering, for which purpose problems are appended at the end of each chapter; but it should also provide useful refresher reading for engineers already following the power plant line.

The background of the authors—Mr. Skrotski having formerly been in the System Engineering Department of Consolidated Edison Company of New York and recently become Assistant Editor of Power, and Professor Vopat in the Mechanical Engineering Department of Cooper Union—affords an excellent combination of engineering experience with first-hand knowledge of the needs of students in heat-power engineering.

There are 509 pages, 6 × 9 in. fully illustrated and the price $5.00.

The Efficient Use of Fuel

Prepared by the Ministry of Fuel and Power

This authoritative British handbook was assembled by 140 engineers, scientists and industrial associations and is replete with information about fuels and their uses in a wide diversity of industries.

British coals and manufactured gas form the bulk of the fuels considered; and a brief chapter is devoted to oil and its utilization. To assist the reader, a complete bibliography of Fuel Research Papers is identified.

Combustion calculations use the lower calorific values of fuels and American readers must be cognizant of this for here the higher value is standard. In other respects the methods are similar in both countries. Thermodynamic treatments are similar to our own and refer to such American authorities as W. H. McAdams. Occasionally an unguarded statement is evident; e.g., steam "is clean, odorless and tasteless" put this reviewer in a brown study.

Steam-boiler practices are considered at length, but the Lancashire and other "shell" type boilers are so conspicuous that one may, erroneously, consider the book outmoded. A wide variety of industrial furnaces and central-heating methods are discussed, power-plant instruments outlined and test methods exemplified. In the matter of instruments some dearth of modern devices and method is noted.

The book has a fair index and each of its thirty-four chapters has a short compendium in the Table of Contents.

Quoting from Dr. John E. Olsen's Foreword to the American Edition: "the college student would find a very clear and explicit explanation of the topics studied—the technical expert will find the volume a valuable addition to his library."

Code of Minimum Requirements for Instruction of Welding Operators—Part A—Arc Welding of Steel 3/16 to 3/4 In. Thick

In 1942 the American Welding Society published a booklet to establish suitable training standards for vocational courses in welding at that time. This has now been revised to make it applicable to the post-war training of welding operators, including returning veterans.

Primarily the 83-page revision embodies a modification of the manner of presentation, although some changes in the exercises and lecture information have been made to provide for a more inclusive course. Topics covered include: Design of Positioning Equipment; Design and Use of Testing Apparatus; Welding Electrodes; Suggested Exercises; and Annotated Bibliography of Publications Relating to Arc-Welding. Price 50 cents.